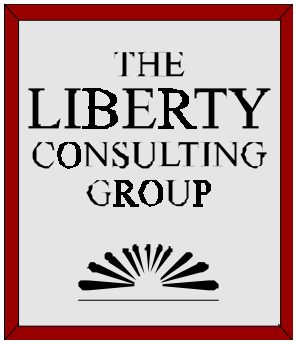
First Report
of the Investigation of
Commonwealth Edison's Transmission
and Distribution Systems

Presented to the:

Illinois Commerce Commission

By:



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Chapter One – Introduction

I. Background

Commonwealth Edison *(ComEd)* is a large electric utility that has more than three million customers and serves more than 70 percent of the population of Illinois. ComEd's service territory encompasses about 400 municipalities including the city of Chicago; its transmission and distribution *(T&D)* system includes more than 700 substations.

During 1998, ComEd's customers experienced a larger number of outages than in prior years. ComEd also experienced equipment outages in Chicago and in other parts of its service territory during July and August 1999. These equipment outages caused large numbers of its customers to lose electric service for periods from several hours to days during hot weather. The Illinois Commerce Commission *(Commission* or *ICC)* is concerned that these equipment outages and associated interruptions of electric service have threatened the public safety and have put at risk the economic well-being of the citizens of Illinois. The Commission is also concerned that ComEd's distribution and transmission systems may not be capable of providing reliable electric service to customers and, therefore, could place the future health, safety, and economic well being of citizens at risk.

The Commission authorized an investigation into the causes of specific outages that occurred in late July and early August of 1999. That investigation has been referred to as Stage I. The Commission issued the final report from the Stage I investigation on January 3, 2000. The Commission also authorized an additional and more comprehensive investigation of ComEd's T&D system that has been referred to as the Stage II (distribution system) and Stage III (transmission system) investigation. The Commission announced on October 29 that it had awarded the Stage II and III investigation to The Liberty Consulting Group *(Liberty)*. The contract between the Commission and Liberty was effective on November 17, 1999.

The results of Liberty's investigation will be published in a series of reports. This is the first such report. At the conclusion of the investigation, the Commission plans to issue a comprehensive report that encompasses the prior series of Liberty's reports and that may update information contained in the earlier reports.

II. Scope and Objectives

The fundamental focus of this review of ComEd's T&D system was to: (a) describe and evaluate ComEd's transmission, distribution, and related management systems as they existed during the

summer of 1999, (b) provide a statement of electric utility practices that should result in adequate and reliable performance in those systems, and (c) report those areas in which ComEd's systems and practices fell short of those good practices and specify the actions needed to move ComEd to the higher standard.

As a result of the outages that occurred in July and August of 1999, ComEd undertook many initiatives to improve its performance. The changes resulting from these initiatives were occurring during this investigation. The Commission Staff instructed Liberty to not be concerned with these changes and, instead, to concentrate its efforts on the evaluation of the reliability of the T&D systems on a retrospective basis. That is, Liberty's review focused on ComEd's T&D systems and practices as they existed, and as they should have existed, as of the first half of 1999. This report describes and provides conclusions about ComEd's practices and conditions as of mid-1999. It also provides recommendations on what ComEd should do. It may be that ComEd is in the process of implementing some of these recommendations. In some cases, Liberty was aware of ComEd's current plans or actions, and these have been mentioned in this report.

Liberty conducted this investigation of ComEd's transmission and distribution systems according to the Illinois Commerce Commission's request for proposals and the subsequent contract between Liberty and the Commission. The Commission Staff had developed two lists of questions for Liberty to answer: Energy Division, Engineering Department Questions for ComEd Outage Investigation and Distribution Reliability Review and Energy Division, Engineering Department Questions for ComEd Outage Transmission Reliability Review. The Commission Staff asked that Liberty examine two previous investigation reports and determine if ComEd had implemented the recommendations they contained: Report on the Investigation of the Electric Transmission and Distribution Reliability of the Commonwealth Edison Company, by Resource Management International (RMI), dated March 1992 and Investigation of Service Interruptions in the Commonwealth Edison System During the July 12-16, 1995 Heat Wave, by Failure Analysis Associates (FAa), dated November 28, 1995. Liberty considered the statements made by ComEd in its December 23, 1998 response to ICC Chairman Mathias' November 16, 1998 letter requesting an analysis of the implementation of the recommendations made by RMI and FAa. The Commission Staff also asked Liberty to review two October 27, 1998, ComEd management presentations to the ICC, Statement of John W. Rowe and Paul McCoy Presentation to ICC on October 27, 1998, and determine if ComEd had performed the actions detailed therein. Finally, the Commission Staff asked Liberty to review the Stage I report and identify any leads, findings, or recommendations appropriate for inclusion in Liberty's investigation.

The Commission stated its goals for the project. Those goals, which were adopted by Liberty's investigation, were to evaluate ComEd's:

1. planning, procedures, and practices used to mitigate any deficient system performance
2. planning for and execution of emergency response and system restoration efforts

3. internal and external communications related to outages and service restoration
4. inspection, maintenance, replacement, and upgrading of equipment and overall transmission and distribution system
5. system performance compared to other major metropolitan service territories, detailing significant differences and similarities in system operation, planning, and design
6. organizational and management structure and the adequacy of performance measures used to evaluate personnel and system reliability.

III. Investigation Methods

Liberty's proposal for the investigation of ComEd's transmission and distribution systems contained a preliminary work plan. That plan called for an orientation with the ICC's Staff to discuss and clarify the objectives of the study. An orientation was also held with ComEd to discuss facility and procedural aspects of the study, and the protocols that would be used by Liberty to acquire information. The preliminary work plan also indicated that Liberty would perform diagnostic interviews and submit initial data requests that would be required to develop a detailed work plan for the remainder of study. Liberty completed these steps in December and completed the detailed work plan on December 30, 1999.

The substantive aspects of the investigation started at the beginning of this year. The methods used were those typical of a management audit in that Liberty acquired information from ComEd through a series of data requests and interviews. Liberty performed analyses on the information, developed hypotheses about the strengths and weaknesses of ComEd's systems and processes, tested those hypotheses through additional analysis and team discussions, and prepared conclusions and recommendations. Liberty also performed field inspections of ComEd's facilities. The following chapters of this report contain endnotes that provide references to Liberty's data sources. To determine whether ComEd's practices were consistent with good utility practices, Liberty drew upon the experience of team members and visited other utilities.

Liberty organized its team in four areas: distribution system, transmission system, substations, and management. Within these major areas, Liberty defined a total of 24 tasks, each of which would lead to a chapter in one of the major reports.

IV. Contents of This Report

In addition to this introductory chapter, this report contains ten chapters that present the results of Liberty's investigation into several areas, including:

- T&D organization and budgeting practices.
- Reporting of system reliability information
- Distribution system planning, design, and protection
- Distribution system operations and maintenance
- Substations.

The chapters are:

Two:	T&D Organization
Three:	T&D Budgeting
Four:	Assessment and Reporting of System Reliability Information
Five:	Distribution System Planning
Six:	Distribution System Design
Seven:	Distribution System Protection
Eight:	T&D Lightning Protection
Nine:	Distribution System Operations and Maintenance
Ten:	Distribution System Conditions
Eleven:	Substations

Liberty found that many aspects of ComEd's systems and practices met good utility practices. For example, and in general, Liberty found no major deficiencies in the fundamental design of the distribution system or in the way ComEd operated the distribution system. The most significant findings and recommendations related to less than adequate systems and practices are:

- Funding for T&D was inadequate during most of the 1990s. (Chapter Three.)
  - ComEd delayed implementation of a customer-based outage reporting system. (Chapter Four.)
  - ComEd increased the interval, and had a large backlog, of testing protection system relays. (Chapter Seven.)
  - ComEd did not have a plan to replace old relays or to install new monitoring and control equipment on older parts of its system. (Chapter Seven.) ComEd did not track the age and loading conditions so as to know the end of life for key distribution system components such as cables (Chapter Ten) and transformers (Chapter Eleven).

  - ComEd did not adequately upgrade, reinforce, or replace aging components in its distribution system. (Chapters Five and Ten.)

  - ComEd had a very large backlog of corrective maintenance items (Chapter Nine) and allowed the general condition of the distribution system to deteriorate (Chapter Ten.)

- Cost controls dominated the T&D organization's goals and objectives. The organization did not have a structure that focused on customer service and T&D reliability. (Chapter Two.)

- ComEd did not use conservative distribution system planning assumptions and did not adequately reinforce its distribution system so that it could have supplied reasonably expected loads. (Chapter Five.)

- ComEd did not provide direct-stroke lightning protection on all of its substations. (Chapter Eight.)

- ComEd did not perform the diagnostic testing that would have been required to assess the condition of its distribution system and substations. (Chapters Nine and Eleven.)

Liberty recognizes that as the investigation continues, new information may be obtained that could result in additions or changes to the findings in the areas treated by this first report. If this occurs, Liberty will present those findings or changes in subsequent reports or in the comprehensive report that will be produced at the end of the study.

V. Terms and Definitions

Liberty has attempted to write this report so that it could be understood by people who are not familiar with technical aspects of electric transmission and distribution systems. However, there were instances in which technical terms had to be used to accurately explain ComEd's systems. This section provides a summary of basic terms that are associated with electric transmission and distribution systems, starting with the units of measure for electricity. Many of the definitions in this section were taken or quoted from ComEd's web site, http://www.ucm.com/comed/business.

Units

Amp or Ampere is the unit of measure for the electrical flow in a conductor or wire.

Current is the rate at which electricity flows. Current is measured in amps.

Volt is a measure of the force that transmits electricity.

Kilovolt (kV) is a measure of electric voltage equal to 1,000 volts.

Watt is a unit of electrical power. Volts multiplied by Amps equals watts.

Kilowatt (kW) is the electric power equal to one thousand watts.

Megawatt (MW) is the electric power equal to one million watts or 1,000 kilowatts.

Kilowatt-Hour (kWh) is an amount of electrical energy equal to one kilowatt for one hour.

Transmission and Distribution (T&D)

Transmission System is the overhead and underground high-voltage lines, substations, and other electrical equipment that are used to deliver electricity from generating stations to the distribution system. ComEd's transmission system carries electricity at 34,500, 69,000, 138,000, 345,000, and 765,000 volts.

Distribution System is the overhead and underground lines and other electrical equipment that is used to deliver electricity from the transmission system to customers. ComEd's distribution systems use primary voltages of 4,160 and 12,500 volts.

Substation is a facility that contains transformers and other electrical equipment. Substations change the voltages in the electric delivery system and connect generating stations, the transmission system, and the distribution system. There are **five types** of substations:

(1) **Generation Station Switchyards** are used to connect electric generating stations to the transmission system.

(2) **Transmission Substations** convert 765,000 volts to 345,000 volts and 345,000 volts to 138,000 volts. The designation that ComEd uses for transmission substations is **TSS**. Some of these substations also convert 138,000 volts to 34,500 volts or 12,500 volts.

(3) **Transmission Distribution Centers** convert 138,000 volts to 12,500 volts. The designation that ComEd uses for transmission distribution centers is **TDC**.

(4) **Distribution Centers** convert 34,500 volts to 12,500 or 4,160. The designation that ComEd uses for distribution centers is **DC**.

(5) **Electric Service Stations** are used in the distribution system to deliver electricity to one customer. The designation that ComEd uses for electric service stations is **ESS**.

Electrical Equipment and Other Terms

Ampacity is the electric current rating or capacity of a particular piece of equipment, such as a cable. Ampacity is normally stated as a number of amperes or volt-amperes.

Arrester is a device used to protect the electric delivery system and other equipment from the high voltages and currents typically caused by lightning strikes. **Elbow Lightning Arrester** is a specially designed lightning arrester that can be placed on underground electric equipment such as transformers and switching cabinets.

ATO or **Automatic Throw-Over** device is used to automatically transfer electric power from one source to another.

Bus is a connection point in an electrical system for several pieces of equipment.

Cable is the insulated material used to carry electricity in underground systems. Cable is classified according the voltage it is intended to carry, the material used to carry the electricity, the type of insulation, and its protective jacket.

Circuit Breaker or **breaker** is a switch that is used to connect and disconnect electric circuits.
Coincidence Factor is determined by dividing the maximum simultaneous peak electric load of a system by the independent, non-simultaneous peak demands of each of the individual components attached to it.

Conductor is a metallic component normally made of either copper or aluminum that is used to carry electricity.

DDC or **Degree-Days Cooling** is defined as 65° Fahrenheit (35.4° Celsius) subtracted from the average hourly temperature in °F, accumulated hourly over a defined time period and divided by 24 hours. Only hours where the average hourly temperature is above 65° F are included.

DDH or **Degree-Days Heating** is defined as the average hourly temperature subtracted from 65° Fahrenheit (35.4° Celsius) accumulated hourly over a defined time period and divided by 24 hours. Only hours where the average hourly temperature is below 65° F are included.

Dielectric material is a non-conducting, insulation material that can consist of a solid material, air, vacuum, and certain gases like Sulfur Hexa-Fluoride.

Distribution Lines feed power at distribution voltages (4,160 volts and 12,500 volts) to distribution transformers that step the voltage down to lower voltages for customer use. Distribution lines are also called **feeders**. These lines are the backbone of the distribution system and usually consist of three conductors. A specific feeder that supplies power to transformers that are connected to a low voltage network is called a **network feeder**.

Fault is a short-circuit or an unintentional connection between conductors or between a conductor and ground. **Fault current** is the flow of electricity through this unintentional connection.

Feeder Stem is a term used by ComEd to describe the main trunk line or main conductors of the feeder.

Instantaneous trip device is an element in a protective relay that operates immediately at a predetermined setting to trip a breaker.

Impedance is the electrical resistance or impediment to current flowing in an electrical circuit. It generally contains both resistive (in phase) and reactive (out of phase) components.

Independent Power Producer *(IPP)* is a company that generates electricity and provides the electricity to ComEd through connections to ComEd's system.

Isokeraunic level is a term that refers to the number of days in which at least one lightning stroke occurs during the day. Florida has a US high isokeraunic level of 100 while the U.S. West Coast has a US low isokeraunic level of 5.

Insulation involves the ability of air or solid material to maintain the electric current and voltage in the electric wires (conductors) and other equipment. The electric insulation must be able to

withstand the normal voltage present on equipment plus surges caused by lightning and switching. If the voltage surge is too high, it will cause a break down of the insulation.

Insulators are used to separate or isolate equipment that is carrying electricity from other equipment.

Joint or **splice** is a connection between two insulated cables.

Load factor is defined as the average load divided by the peak load. More specifically, it is obtained by dividing the energy over a defined period of time by both the peak load (stated in similar units) and by the defined period of time (stated in units compatible with the energy.)

Manholes are underground enclosures that protect equipment while permitting access to that equipment or cabling.

Neutral inductor is a device placed on a transformer to reduce the magnitude of line-to-ground fault currents.

Oil-Impregnated Paper is the most commonly used insulation on cables in Chicago.

Outage is the failure of part of the electric delivery system. An outage may cause an **Interruption**, which is a loss of electric service to a customer.

Oscilliography is the high speed recording of electrical parameters such as currents and voltages during a fault.

Parallel operation of a transformer refers to the situation in which two transformers are operated to equally share the electric load. This is similar to two engines operating on a motor boat where each engine supplies half the power to run the boat. The act of putting the transformers together for the same load is referred to as paralleling.

Protective Relays are used to detect abnormal conditions. These relays often are used to operate circuit breakers.

Radial Circuit is part of the transmission system or a distribution line that extends from a substation to customers without an alternate supply of power.

Ratings are the conditions that define safe operating limits on electrical equipment. Ratings include things such as voltage, power, and temperature.

Recloser is a device that opens a circuit when a fault is detected and then closes the circuit after a short delay. A recloser is an automatic device used for sensing and interrupting faulted (shorted) line segments. After the fault has been interrupted, the recloser will automatically close to test the circuit. If the fault is gone, the recloser will stay closed. If the fault is not gone, the recloser will open and remain open.

Reclosing relay is a special type of relay that initiates automatic closing of the circuit breaker back onto the feeder, thus allowing relatively quick restoration of service for momentary faults like those caused by lightning and wind.

Ring Bus is multiple sections of electrical bus interconnected (usually with breakers) in such a fashion as to form a circular electrical path. Loads and sources are usually tapped off the ring bus along its length. The advantage of a ring bus is its high operating flexibility. The disadvantage of a ring bus is its high cost and greater space requirement.

Sectionalizer is a feeder device that can sense a faulted condition on a line and open after a predetermined number of faults. The device will open and remain open at the same time that an upstream recloser or breaker opens. This is a relatively inexpensive line device that does not interrupt fault current, but can isolate a faulted line when an upstream device has opened. Usually, the upstream device, such as a breaker or recloser, will subsequently close restoring power to the remainder of the line.

Supervisory Control and Data Acquisition System (SCADA) is a computer-based system used to monitor conditions, record data, and operate equipment, such as circuit breakers, from remote locations.

Through-fault refers to the condition when a short circuit or fault occurs on the load-side of a transformer. The transformer must now supply a large amount of current and that current is referred to as through-fault current. This current will stress the windings of the transformer and can ultimately result is a transformer failure. **Transformer** is a piece of equipment that is used to increase or decrease the voltage of electrical energy. An **oil-filled transformer** is one that uses oil for electrical insulation and cooling.