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U.S. DEPARTMENT OF ENERGY
FEDERAL ENERGY REGULATORY COMMISSION

MASTER

THE CON EDISON POWER FAILURE OF JULY 13 AND 14, 1977

FINAL STAFF REPORT

JUNE 1978

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PREFACE

The day after the July 13, 1977, failure of the Consolidated Edison Company (Con Edison) system, President Carter directed the Federal Power Commission (FPC) to investigate this failure "to ascertain the reasons why it occurred and to recommend specific actions to be taken to prevent a recurrence."[1] On August 4, 1977, the FPC issued a preliminary staff report containing its initial findings and recommendations. That report set forth several tentative conclusions and noted that the investigation would be continued so that the staff could "study in depth the design and operation of the Company's system for the purpose of suggesting further corrective measures." The staff, now of the Federal Energy Regulatory Commission (FERC), has continued to investigate the design and operation of the Con Edison system to confirm or modify the initial findings and to suggest additional corrective measures. This report presents the results of that investigation.[2]

The investigation focused on the causes of the power failure and on causes of the delay in the restoration effort. Study of these led to consideration of several more general areas, including the adequacy of Con Edison's system planning as related to reliability; its design approaches to protecting equipment from disturbance, particularly lightning; the scope, detail, and currency of emergency plans and procedures; and the training and supervision of system operators.

Following a brief introduction and summary of the entire report in chapter I, the next three chapters describe in relatively nontechnical language the significant characteristics of the Con Edison system, the basic principles of power supply reliability, and the failure and restoration of the Con Edison system on July 13 and 14, 1977. Chapters V and VI contain more technical analyses of the failure and restoration, respectively. Conclusions and recommendations are detailed in chapter VII.

During the period following the failure, other organizations and agencies have made independent investigations. The staff has reviewed reports of these studies, and has compared their conclusions with its own. The results of this effort are contained in chapter VIII.

Appendixes A to O are included to provide background information on the Con Edison system, the system disturbance, and the restoration; to illustrate the type of data used in the investigation; and to substantiate the analysis and the conclusions of the FERC staff. Appendix C describes organizations of electric power companies of which Con Edison is a member. Appendix D consists of transcripts of telephone conversations of key personnel at the time of the system disturbance. In appendix E, a consultant, Joseph G. Colmen, gives an analysis of Con Edison's methods for selecting and training system operators. Appendixes F, G, H, K, and L give technical background information. Appendix I describes operating procedures related to emergencies. A detailed account of the restoration is in appendix J. Appendix M tells how neighboring systems were affected by the system collapse. Various recommendations made by investigating bodies, to help prevent system disturbances or to lessen the impact of them, are given in appendixes N and O; Con Edison's related actions are given with each.

In conducting the investigation and preparing this report, the FERC staff has made use of information from various sources, including Con Edison, adjoining electric utility companies, the New York Power Pool (NYPP), the New England Power Exchange (NEPEX), and the Pennsylvania-New Jersey-Maryland Interconnection (PJM). Company personnel were questioned concerning the technical planning and operation of the system and concerning the events of July 13 and 14. In addition, a private consultant was employed to conduct a special investigation related to Con Edison's selection and training of system operators. Responsibility for the evaluations, conclusions, and recommendations in the report, however, rests with the FERC staff.[3]

In its preliminary report concerning the July 13 failure, the staff included a chapter "Additional Recommendations," recommendations directed to all utilities and power pools throughout the country. It was

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[1] The FPC orders instituting the investigation are reproduced in appendix A.

[2] Under the Department of Energy Organization Act, responsibility for power supply reliability matters has been delegated to the Economic Regulatory Administration rather than to FERC. However, because this investigation was underway at the time of reorganization, the FERC staff members involved continued the work.

[3] A number of members of the staff of FERC and the predecessor FPC have participated in the investigation of the power failure and in the writing of this report. Their names are listed in appendix B.

recommended that each major utility and power pool undertake a special analysis and self-examination for the purpose of assuring that the experience of Con Edison is not repeated. It was further recommended that each of the nine regional reliability councils require reports from each of its major utility components, describing the results ot the recommended reviews, and prepare a report to FPC, setting forth the results of the recommended self-examination. Each of the nine councils has taken steps to comply with the recommended procedure. In view of the recent creation of the Department of Energy (DOE) and the revision of the organizational structure for exercising Federal responsibility for bulk-power-supply reliability, the Economic Regulatory Administration will assume responsibility for review of council activities designed to comply with these recommendations, including review of the reports as they are submitted.

CONTENTS

Chapter I

INTRODUCTION AND SUMMARY

On July 13, 1977, the entire electric load of the Con Edison system was lost. New York City and Westchester County were plunged into darkness. Electric service to more than 8 million people in the metropolitan area and to the commercial and industrial users of this area was interrupted for periods from 5 to 25 hours. Although there was no direct loss of life, the economic losses were very large, in part because of extensive looting and malicious property damage.

The collapse of the Con Edison system[1] resulted from a combination of natural events, equipment malfunctions, questionable system design features, and operating errors. Of paramount importance, however, was the lack of preparation for major emergencies such that operating personnel failed to use the facilities at hand to prevent a systemwide failure. Even after the loss of major transmission facilities, a complete system shutdown could and should have been prevented by a timely increase in Con Edison's in-city generation or by manual load shedding.

The long delays in restoring service were also the result of multiple causes. Among the most significant of these causes were the loss of underground-cable insulating-oil pressure and the inability to restart certain generating facilities without power from outside sources, although these facilities were designed to have such a restart capability.

At 8:37 on the evening of July 13, during a severe thunderstorm, lightning struck two extra-high-voltage lines in northern Westchester County, at the northern extreme of Con Edison's service area. At 8:56 p.m., two more lines were struck. Protective equipment on the lines operated imperfectly after each of the strokes, with the result that three of the four lines remained open, and a major generator and several other vital transmission lines were forced out of service. Transmission ties to other utilities made up the power deficit but became increasingly overloaded. The emergency worsened until, by 9:30 p.m., all ties to external sources were open, either through protective equipment operation or as a result of actions taken to protect neighboring systems. The customer load was too great for Con Edison's available in-city sources of power. At 9:36 p.m., the system was completely shut down.

The process of restoration was difficult and slow. An immediate attempt to restore service to major parts of the system was unsuccessful and resulted in significant equipment damage. Con Edison operations management quickly developed a more comprehensive restoration plan, but its implementation was delayed by lack of emergency power and by equipment malfunction. The first significant customer load was not restored until about 2 a.m., July 14, and it was about 10 a.m. before load areas began to be restored at a steady pace. Restoration was completed shortly after 11 p.m., July 14.

Not since the massive Northeast power failure of November 1965 has an electric service interruption raised so much concern over the reliability of power systems. That catastrophic blackout focused national attention on the problem of power supply reliability, caused an intensive self-examination on the part of the industry, and led to governmental intervention in power-supply-reliability matters for the first time. Extensive studies of that power failure were made to understand its causes as well as to seek to prevent recurrences. Specific recommendations for accomplishing this purpose were made by the Federal Power Commission (FPC), other regulatory agencies, and by various elements of the industry.[2]

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[1] As used in this report, "Con Edison system" means the system that includes facilities used to transmit and distribute electricity to customers of the Power Authority of the State of New York (PASNY) located within the geographic area served by Con Edison, as well as certain facilities owned by PASNY but operated by Con Edison (Indian Point unit No. 3 and Astoria unit No. 6). A map of the service area, showing major facilities, is inserted inside the back cover of this report.

[2] One result of the 1965 failure was the formation of Regional Reliability Councils, led by the Northeast Power Coordinating Council (NPCC) in early 1966. By 1970 Regional Reliability Councils covered the entire contiguous United States. Each of these councils has developed an extensive program for coordinating the planning and operations of its members with a view to optimizing the bulk-power-supply reliability of the interconnected regional system. Standing committees of these councils meet frequently to coordinate activities of member systems. In addition, a number of task forces have studied and reported on many of the more important reliability problems. An elaborate system has been developed for periodic reporting of a great variety of information to the Federal Government, including load and capacity projections 10 and 20 years into the future.

Although the Con Edison power failure of July 1977 was technically different from the 1965 event, the 1965 and 1977 events have an important feature in common: in both cases, a low-probability event created an emergency in one sector of the system, and after that event, a combination of equipment malfunctions and incorrect operator actions allowed the emergency to grow to major proportions. It is not possible to prevent an occasional localized power failure. It is possible technologically to reduce to an extremely low value the probability that such a contingency will lead to a systemwide failure, or to an extended interruption on a major portion of a large system, such as Con Edison's.

Just as in 1965, a number of questions require answers:

(1) What were the specific causes of the failure?

(2) If equipment malfunctions and operator errors contributed, could they have been prevented?

(3) To what extent was Con Edison prepared to handle such an emergency?

(4) Did Con Edison prudently plan for reserve generation, for reserve transmission capability, for automatic equipment to protect its system, and for proper operator response to a critical situation?

This report attempts to answer these questions. Some of the answers are known from obervations and records of the event. Others elude precise determination and must be based on careful weighing of estimates and judgments. However difficult these questions may be, it is important that they be answered as fully and objectively as possible. There is much to be learned from the circumstances of the failure and much to be gained by applying the new knowledge to help assure that such a disaster will not occur again.

CAUSES OF THE FAILURE AND DELAY IN RESTORATION

The complex events that resulted in the failure are described briefly in chapter IV and are analyzed in detail in chapter V. The principal immediate causes of the failure were—

(1) Two severe lightning strokes, about 18 minutes apart, each causing simultaneous flashovers of a pair of major transmission circuits, for a total of four line faults

(2) Equipment malfunctions preventing the proper automatic restoration to service of three of the four lines struck, and leading directly to loss of additional transmission circuits, resulting from a loose lock nut on a control rod of a circuit breaker and a bent contact on a protective relay, both at the Millwood West Substation[3]

(3) An improper relay circuit design that caused a transfer trip signal to be sent unnecessarily, locking out circuit breakers on a vital transmission line (Y88) at Ladentown

(4) A series of operator failures, including—

(a) Failure to recognize that a critical interconnection to the West (Y94) was effectively unavailable

(b) Failure to assure that scheduled 10- and 30-minute reserve generation was actually available and that there was proper assignment of generation to automatic control in accordance with New York Power Pool (NYPP) requirements

(c) Failure to pay strict attention to short-time emergency (STE) ratings of critical facilities

(d) Failure to call for increased generation promptly

(e) Failure to shed load promptly under circumstances clearly requiring such action and in response to repeated advice or directives from the NYPP senior pool dispatcher

The losses of facilities resulting from the lightning strokes and directly related equipment malfunction substantially exceeded the contingencies that are considered credible and that bulk power systems are designed to withstand without loss of load.

The process of restoring service after the July 13, 1977, failure is described briefly in chapter IV and is analyzed in detail in chapter VI. The restoration did not proceed smoothly; unexpected delays combined to extend the process over about 25 hours, much longer than should have been necessary. The immediate causes of the delay were—

(1) An unexpected drop in pressure of insulating oil below the level required for proper operation of extra-high-voltage underground transmission cables

(2) Inability to start certain generators, which were designed and equipped to be started without an external power source during emergencies

(3) Difficulties in maintaining voltages within safe limits, resulting in second interruptions in restored areas and further equipment damage

(4) Damage to some transformers and other equipment resulting from an unsuccessful attempt at rapid restoration with limited sectionalizing of the system

(5) Instances of inadequate coordination of restoration efforts and lack of fully current restoration procedures providing sufficient detail and clarity

ACTIONS TAKEN SINCE THE FAILURE

After the restoration of service to all customers of the Con Edison system, efforts were begun to determine the causes of the failure and to identify the measures

[3] The most heavily loaded system generator was also lost in the initial disturbance, but this was the result of proper operation of protective equipment.

necessary to prevent recurrences. President Carter directed FPC to investigate the failure. Con Edison created its Board of Review, consisting of a number of its executives, as well as several prominent consultants, and began its own intensive investigation. In addition, intensive investigations were initiated by the city of New York, by the State of New York, and by the New York Public Service Commission (NYPSC), as well as by committees of Congress.

Reports reflecting partial or complete results of all of these investigations have been prepared and issued. On August 4, 1977, the FPC staff issued a preliminary report containing a series of recommendations. Reports have also been issued by NYPSC, the city of New York, and the State of New York (Clapp Report). Although the various reports differ in emphasis and in details of recommendations, there is general agreement that the complete shutdown of the Con Edison system could have been prevented if all protective equipment had functioned correctly or if the system operators had taken timely action to compensate for the lightning-induced transmission-circuit outages.

The conclusions in this report generally confirm those in the August 4, 1977, FPC report. As a result of subsequent investigation, however, the staff of the Federal Energy Regulatory Commission (FERC) places relatively more emphasis on operating inadequacies and less emphasis on unavailability of facilities than was expressed in the earlier FPC report.

A number of actions have been taken by Con Edison partly in response to recommendations contained in these reports; others are in the implementation stage. These actions are described in more detail in chapter VII of this report. They consist largely of—

(1) Measures to strengthen system readiness for emergencies, including reduction of transmission imports during thunderstorms, regular testing of fast-load-pickup capabilities and of emergency facilities, and more detailed specification of emergency measures

(2) Measures to strengthen system command and control, including addition of positions to the control center staff, improvements of control center information displays, simplification of load-shedding controls, and regular testing of control personnel

(3) Revisions of system design and operating concepts, notably the use of automatic load shedding to relieve tie-line overloading and minimize the need for separation from other systems

PRINCIPAL CONCLUSIONS

Chapter VII contains a description of the conclusions reached by the FERC staff on the basis of its investigation of the July 13 power failure and subsequent restoration of the system. The principal conclusions follow.

Management Responsibility

The management of Con Edison must bear responsibility for the failure of the system to withstand the July 13, 1977, emergency without a major, extended interruption. The inadequate performance of some elements of the physical equipment and the operating organization reflect insufficient management attention to reliability matters and particularly to emergency planning and operations.[4] With its dense population and heavy concentration of important facilities, institutions, and major national commercial enterprises, the city of New York requires a particularly high degree of electric power supply reliability. Emergency procedures must be planned to minimize the possibility of major service interruptions and to assure that restoration is accomplished expeditiously in the event that such an interruption occurs. Operating management must give constant attention to the possibility of bulk-power-supply failure, and must make certain that all operating personnel are prepared to deal with emergencies promptly and correctly. The events of July 13 and 14 indicate that management had not exercised the degree of diligence necessary to assure that these requirements would be fulfilled.

Selection, Training, and Supervision of System Operators

The system operator failed to follow proper procedures in dealing with the July 13 disturbances on the Con Edison system. Clearly, he was not prepared for the emergency. Although the control and information facilities available to the operator were not of the most modern design, they were adequate. If they had been used properly, it is reasonably certain that the system collapse could have been prevented.

The program for selection and training of system operators in use by Con Edison provided reasonable assurance that persons so employed would have extensive experience in system operation, as well as some training in the use of control procedures and equipment during emergencies. The events of July 13, however, emphasize the importance of rapid and accurate assessment and action in stress situations. There is need for a thorough reexamination of the program for operator development as it relates to equipment, procedures, and decision criteria to be employed during emergencies. In addition, there appears to have been no provision for assuring (through periodic testing or other means) that the ability of the system operators to perform properly under emergency conditions was maintained.

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[4] This report is not intended as an expression of opinion as to any legal cause and effect relationships between the power supply interruptions and social losses.

System Planning and Design

Criteria for system planning and design employed by Con Edison are generally consistent with those established by the Northeast Power Coordinating Council (NPCC) and NYPP. The transmission system design and its operation just before the first contingency on July 13, 1977, were within established reliability limits. Reliability criteria applied to the Con Edison system, however, should recognize the extreme sensitivity of the city of New York to failure of its power supply. Criteria applied to typical systems in the Northeast may be inadequate for Con Edison in light of the potentially severe consequences of a major service interruption on its system. In addition, where reliability criteria admit of engineering judgment in their implementation, Con Edison should design and operate its system well within a cautious interpretation of such criteria. The July 13, 1977, failure exposed situations in which this was not the case.

System Operations

Although the Con Edison system was not exceeding import limits established by NYPP criteria on July 13, there was insufficient recognition of increased transmission vulnerability during thunderstorms. Operating deficiencies contributed importantly to the collapse, especially the failure to have some generators on automatic generation control, the failure to verify regularly the expected response of reserve capability, and the failure to report out-of-service generation promptly. It is evident that greater attention must be given to the possible occurrence of contingencies and to means for assuring that emergency equipment and procedures will be adequate when called upon.

Maintenance, Inspection, and Testing of Equipment

Staff examination of the Con Edison program for maintenance, inspection, and testing of equipment found that it was well conceived and generally well administered. Equipment failures, nevertheless, contributed to the system collapse. Among the causes were two specific pieces of faulty equipment at a critical substation (Millwood West) and an improper transfer trip relay operation (Buchanan South) affecting a critical line (Y88). It is, therefore, evident that the inspection and testing program is in need of further improvement with particular emphasis on procedures for verifying the adequacy of tests and maintenance and on testing of interrelated groups of protective devices.

Restoration Plans, Procedures, and Equipment

In July 1977 Con Edison was not adequately prepared for a major emergency. Although operating personnel understood restoration procedures and performed well in difficult circumstances, the plans and procedures for restoring service that existed were not up to date and in some cases not clear and detailed. Serious problems and delays in restoration were caused by the lack of emergency power supplies or failure of some of those that did exist. Delays caused by the necessity of reestablishing power supply to insulating oil pumps showed this aspect of the system design to be unsound; adequate pressures could not be sustained in underground high-voltage transmission cables for sufficient periods without pumping. Provision for voltage control was also inadequate.

CON EDISON CORRECTIVE ACTIONS

Intensive studies made by Con Edison since the collapse have identified weaknesses in planning, design, operations, and training. A number of corrective measures have been formulated. The actual changes in operating practices and equipment that have been made since the blackout, plus those planned for early implementation, are responsive to most of the FERC staff recommendations. Although there can be no guarantee that an electric power system will never fail, the measures undertaken by Con Edison, coupled with maintenance of alertness to the possibility of major emergencies, should substantially reduce the probability of recurrence of the events of July 13 and 14.

PRINCIPAL RECOMMENDATIONS

Chapter VII contains a series of detailed recommendations stemming from the various conclusions reached by the staff as a result of its investigation. These recommendations relate to the system as it existed on July 13, 1977. As mentioned previously, many of these recommendations have been implemented or are in process of implementation. The principal recommendations follow.

System Control

The command and control capabilities of the energy control room should be strengthened through redesign of procedures for selection, training, and stress evaluation of control personnel, specific training of operators in emergency procedures, clarification of channels of authority and terminology used in coordinated operations with NYPP, more direct display of information on the status of key facilities and equipment, and simplification of manual load-shedding controls.

Under Federal sponsorship, a program should be developed to establish criteria for selection of personnel, training, and the evaluation of training methods, together with criteria for control-room equipment, operating procedures, and other elements of the man-machine relationships involved in system operations.

Consideration should be given to Federal licensing of operators of major power systems operating in interstate commerce.

Operating Procedures

Procedures should be established to assure rapid correction of tie-line loadings in excess of their STE ratings, including automatic backup load shedding. There should be strict compliance with NYPP policy for automatic generation control, along with regular testing and verification of fast-load-pickup capability. The "storm watch" procedure established by Con Edison following the July blackout, which reduces energy imports through the northern corridor during storms, should be made permanent. Every effort should be made to make the automatic underfrequency load-shedding system an effective protection against system collapse.

Transmission Protective Systems

All relay schemes affecting the bulk power system must be critically examined to insure their validity relative to possible contingencies. The breaker arrangements at critical substations must be reconsidered in an attempt to achieve a greater degree of independent protection for individual transmission circuits. In addition, the equipment inspection and testing program must be extended to include procedures for verifying the adequacy of specific tests and maintenance actions, as well as procedures for testing of interrelated groups of protective devices.

Restoration Plans, Procedures, and Equipment

A detailed new restoration plan must be developed, which reflects the experiences of July 13 and 14, including measures to control voltage within limits, installations of emergency power supplies at principal oil-pumping locations, and critical evaluation of the feasibility of rapid restoration with limited sectionalizing of the system. The plan must provide for restoration of service to critical city areas in no more than a few hours. Maintenance and periodic testing procedures for emergency power and black-start generation facilities must be strengthened.

Followup on Reliability Recommendations

Procedures should be established for regular reporting by Con Edison to the appropriate regulatory authorities of its progress in implementing these recommendations as promptly as is reasonable. After consultation between company personnel and the staff of the appropriate regulatory authorities, a schedule should be prepared for company compliance with these recommendations, setting forth specific target completion dates together with intermediate dates for reporting of progress toward completion.

OTHER INVESTIGATIONS

The FERC staff has reviewed the reports of the other investigations, those by Con Edison, by the city of New York, by NYPSC, and by the State of New York. In chapter VIII it provides a summary and comparison of the various conclusions and recommendations. There is strong agreement on the technical factors involved in the collapse and slow restoration, but there are significant differences regarding the relative importance of the causes and the necessary remedial actions.

Both the city and State reports conclude that there were major deficiencies in Con Edison's planning, design, and operating practices that directly caused the problems of July 13 and 14 and that these deficiencies were fundamentally management deficiencies. Both reports suggest that the company was underemphasizing its reliability-related activities as a result of financial stringencies or to increase stockholder returns. The city report's recommended remedy for the perceived management deficiencies is to add members to the Board of Directors appointed by the Governor, the major of New York and the Westchester county executive. The remedy recommended by the State report for the poor practices concluded to exist at Con Edison and other New York utilities is for NYPSC to establish detailed bulk-power-transmission design and operating requirements and for the State eventually to take over the bulk-power-transmission system.

The Con Edison report, in effect, agrees that some operating practices were deficient but generally defends its planning and design practices. However, it admits that its reliance on automatic load shedding as a last line of defense was misplaced, that some revisions of its transmission configuration are desirable, and that it was not well prepared to restore a collapsed system.

The FERC staff assigns principal responsibility for the collapse and slow restoration to operating deficiencies, associated with undue complacency at all levels of the company. Overall, the FERC staff report finds that the corrective actions taken and planned by Con Edison generally effectively address the weaknesses on its system identified by the FERC investigation. The actions will improve the operating status and overall reliability of the system. The staff does not find that the institutional measures recommended by the city and State reports are warranted as means to enhance system reliability.

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Chapter II

THE CONSOLIDATED EDISON SYSTEM

The electric service area of Con Edison consists of the five boroughs of New York and the major part of Westchester County to the north. The service area covers about 600 square miles. (See map inside back cover.) Con Edison serves a population of 8,317,000 and supplies electricity to 3,110,000 households. The system is characterized by very high density of electric load resulting from the high population density and particularly from the unique concentration of commercial activity in the city of New York. Con Edison's territory is similar in service requirements to other large urban areas, but by most significant socioeconomic measures, it is at the extreme. Con Edison also has the most extensive underground extra high voltage electric power network in the world.

A map of the Con Edison service area, showing the principal facilities of the company, is inserted inside the back cover.

LOAD CHARACTERISTICS

Con Edison's customer load, as measured by energy supplied over the entire year (1976 data), is about 24 percent residential, 51 percent commercial, 5 percent industrial, and 20 percent governmental. (Nationwide, the proportions in 1976 were 31.6 percent residential, 28.1 percent commercial, and 40.3 percent industrial, with Government consumption divided between commercial and industrial in accord with the type of activity involved.) Because Con Edison's industrial load is relatively small, and because the other load components have highly concentrated demand in daytime and early evening hours, Con Edison has large daily cycles in demand for power, or, stated another way, it has a low average use of its overall capacity to supply power. Figure II-1 shows a graph of Con Edison's load for a typical summer week.

Because of the widespread use of electric air conditioning, Con Edison experiences its highest daily peak demand in the summer, with the summer peak about 40 percent higher than the winter peak. The 1976 peak demand was 7,579 MW, down from the record 8,220 MW in 1973. The decrease since 1973 is viewed as a temporary trend; Con Edison's forecast is for an average growth in peak demand of about 2.7 percent per year to 1995. Total energy supplied by Con Edison to customers in 1976 was 35.8 billion kilowatt-hours (kWh). Con Edison's forecast is for energy supplied to grow at an average rate of about 2 percent per year until 1986 and about 2.8 percent from 1986 to 1997.

GENERATING FACILITIES

In July 1977, Con Edison owned 11 major generating plants in the city of New York, and shared ownership of the Indian Point plant, on the east bank of the Hudson River in Westchester County, and of the Bowline Point and Roseton plants, west of the Hudson in Rockland and Orange Counties. Except for the units at Indian Point, all generating units on the system are either oil-fired steam or oil-fired combustion-turbine units. Indian Point has three nuclear steam units, but of these, only No. 3 (1,013 MW) was operating in July 1977.

Table II-1 lists Con Edison's generating plants, with the numbers of units and total capacity for each type classification. There are at present no coal-fired, gas-fired, or hydroelectric units on the system. One of the 10 Waterside units (No. 7) can be gas fired, but it normally burns oil. Diesel generators are used only for special or emergency service.

Ravenswood Unit No. 3 (1,030 MW), Arthur Kill Unit No. 3 (515 MW), Indian Point No. 2 (1,013 MW) and No. 3 (1,013 MW), Bowline Point Nos. 1 and 2 (621 MW each), and Roseton Nos. 1 and 2 (621 MW each) are tied directly to the 345-kV network at the station step-up transformers. All other major generating units are tied to the 138-kV network.

TRANSMISSION AND DISTRIBUTION

Con Edison's principal transmission system is a 345-kV network, basically oriented south to north, conforming to the geography of the company's service area along the Hudson River, and having extensions to the west at the northern and southern extremes. It provides high-capacity ties between generating plants in the city and along the Hudson River north of the city and the load-center areas in the city and in Westchester County. At the northern end it provides power transmission ties

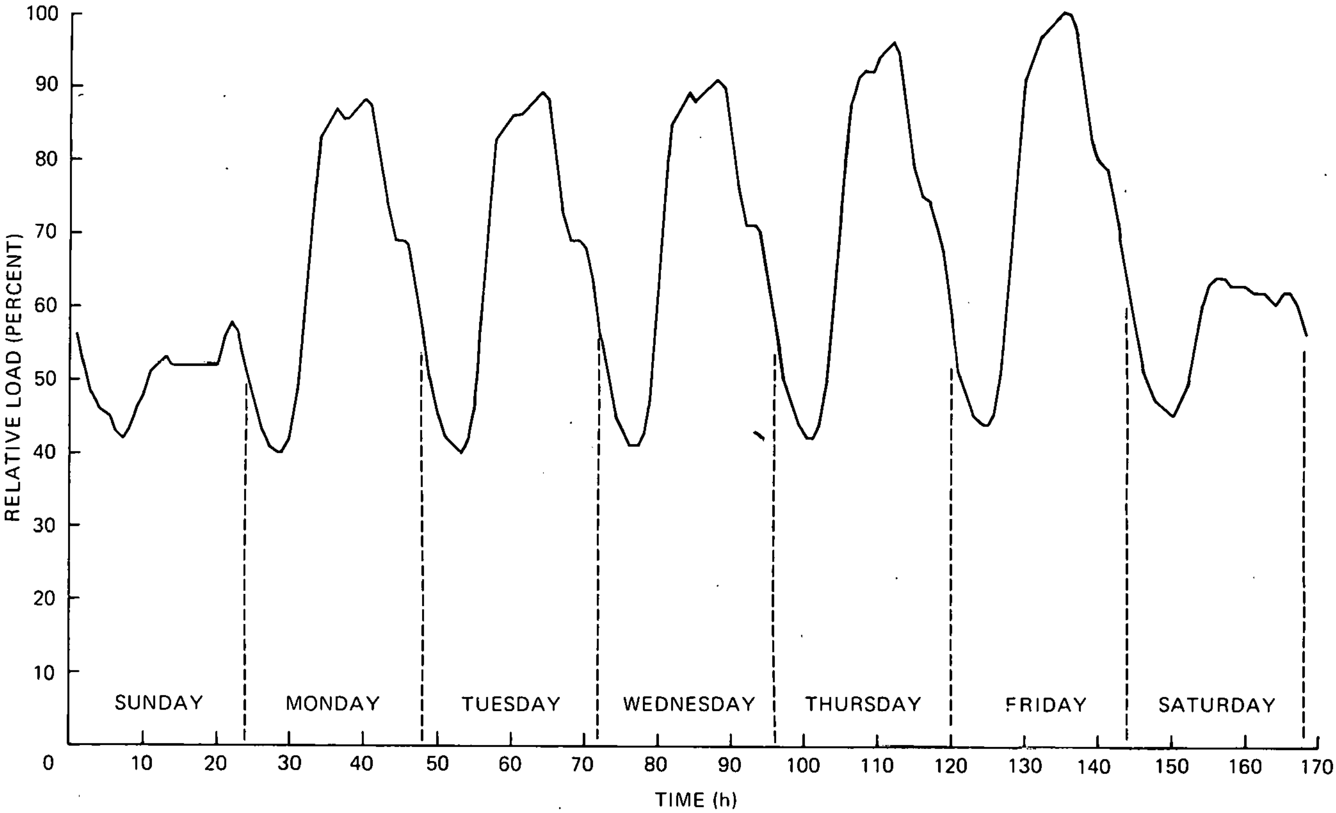

Figure II-1.—Relative hourly loads (portions of weekly peak load, 6,730 MW) for Con Edison for August 1 to 7, 1977. Points give hourly averages for preceding hours, obtained from integrated demand for those hours. Total weekly energy = 737,825 million kWh; load factor = 0.65257.

Table II-1.—*Con Edison Generating Facilities, June 1977*

Station name	Steam turbine: Number of units	Steam turbine: Total nameplate rating[1] (MW)	Steam turbine: Fuel type	Combustion turbine: Number of units	Combustion turbine: Total nameplate rating (MW)	Combustion turbine: Fuel type	Summer capability (MW)
Arthur Kill	2	912	Oil	1	16.3	Oil	842
Astoria[2]	6	2,351	Oil	13	744.5	Oil	2,844
Bowline[3]	2	828	Oil	–	–	–	801
East River	3	513	Oil	–	–	–	426
Gowanus	0	–	–	4	688.0	Oil	536
Hudson Avenue	7	700	Oil	5	84.6	Oil	565
Indian Point[4]	3	2,356	Nuclear	3	61.4	Oil	1,793
Kent Avenue[5]	0	–	–	2	28.0	Oil	9
Narrows	0	–	–	2	393.1	Oil	315
Ravenswood	3	1,828	Oil	11	481.8	Oil	2,185
Roseton[6]	2	497	Oil	–	–	–	480
Waterside[7]	10	602	Oil	1	14.0	Oil	394
59th Street	5	185	Oil	2	34.2	Oil	157
74th Street	4	209	Oil	2	37.2	Oil	181
Total	–	10,981	–	–	2,583.1	–	11,528

[1] Manufacturer's rating when units were purchased. Con Edison's share of jointly owned units is shown.

[2] Astoria No. 6 is owned by Power Authority of the State of New York but is operated by Con Edison.

[3] Jointly owned: Con Edison, 66.67 percent; Orange & Rockland Utilities, Inc., 33.33 percent.

[4] Indian Point No. 1 is rated at 0, pending installation of emergency core-cooling systems. Indian Point No. 3 is owned by Power Authority of the State of New York but is operated by Con Edison.

[5] Unit No. 1 is out of service.

[6] Jointly owned: Con Edison, 40 percent; Niagara Mohawk Power Corp., 40 percent; Central Hudson Gas & Electric Co., 20 percent.

[7] Unit No. 7 is gas fired only. Units 11 and 13 operate at 25 Hz. Units 8 and 9 are listed as having summer dependable capability only.

to upstate New York and New England. The northwest extension provides capacity to bring in power from the Indian Point, Bowline Point, and Roseton plants, and from other sources to the west. At the southern end, the southwest extension provides transmission to and from New Jersey and other areas to the southwest.

The 345-kV network is supported by an extensive 138-kV grid. Table II-2 lists the individual transmission lines in the 345-kV and 138-kV networks, with principal design data. Of the total of 770 transmission circuit-miles, 454 miles, or nearly 60 percent, operate at 345-kV or above, and 365 miles of the total, or nearly 50 percent, are underground.

Con Edison's distribution system is almost entirely underground, with over 8,000 miles of underground primary feeder cable (mainly 27 and 13 kV), and over 7,000 miles of underground secondary circuits (208 and 120 V). In addition, there is some distribution at 25 Hz, almost entirely for transit load, and a small amount of d.c. distribution in older sections of Manhattan.

Table II-2.—*Existing Con Edison Transmission Facilities*

From	To	Voltage (kV)	Length (mi)	Number of circuits	Summer thermal rating (A)	Principal structure	Number of circuits[1]
Ramapo	New York/New Jersey State line	500	5.35	1	1,214	Steel, single circuit	1
Pleasant Valley	New York/Connecticut State line	345	17.73	1	1,600	Steel, single circuit	1
	Millwood West	345	40.70	2	1,450	Steel, double circuit	4
Sprainbrook	Dunwoodie[2]	345	1.15	2	3,000	Steel, double circuit	2
Fresh Kills	Goethals	345	2.05	2	1,450	Steel, double circuit	2
Ramapo	New York/New Jersey State line	345	3.51	1	680	Steel, double circuit	1
West Haverstraw terminal	Ladentown Switching Station[3]	345	5.03	2	3,000	Steel, double circuit	2
Buchanan South	Millwood West	345	9.60	2	2,300	Steel, quadruple circuit	5
Dunwoodie	Rainey	345	15.25	2	780	Underground or underwater	–
Rainey	Farragut	345	7.37	1	770	Underground or underwater	–
				2	1,200	Underground or underwater	–
Farragut	East 13th Street	345	1.92	4	780	Underground or underwater	–
Sprainbrook	Tremont	345	9.33	1	840	Underground or underwater	–
Farragut	Gowanus	345	3.90	2	1,150	Underground or underwater	–
Gowanus	Goethals	345	12.94	2	855	Underground or underwater	–
Farragut	New York/New Jersey State line	345	3.35	1	925	Underground or underwater	–
Millwood West	Eastview	345	9.35	2	2,800	Steel, double circuit	4
Sprainbrook	East 13th Street	345	21.45	2	795	Underground or underwater	4
Ramapo	Buchanan North[4]	345	16.00	1	3,000	Steel, double circuit	2
Ladentown	Buchanan South[4]	345	10.90	1	3,000	Steel, double circuit	2
Ramapo	Ladentown[4]	345	5.10	1	3,000	Steel, double circuit	2
Bowline Point	West Haverstraw[3]	345	1.69	2	1,150	Underground or underwater	–
Rock Tavern	Ramapo	345	27.40	1	2,660	Steel, double circuit	1

See footnotes at end of table.

Table II-2.–*Existing Con Edison Transmission Facilities*–Continued

From	To	Voltage (kV)	Length (mi)	Number of circuits	Summer thermal rating (A)	Principal structure	Number of circuits[1]
Buchanan North	Eastview	345	18.90	1	3,000	Steel, single circuit	5
						Steel, double circuit	4
Millwood West	Pleasantville	345	3.93	2	3,000	Steel, double circuit	2
Pleasantville	Dunwoodie	345	17.23	2	3,000	Steel, double circuit	2
Eastview	Sprainbrook	345	9.10	2	2,800	Steel, double circuit	4
Goethals	New York/New Jersey State line	230	.39	1	1,410	Steel, single circuit	1
Pleasant Valley	Millwood East	138	40.53	1	800	Steel, double circuit	4
				1	595	–	–
Millwood West	Buchanan	138	9.58	2	1,200	Steel, quadruple circuit	5
Dunwoodie	Sprainbrook	138	1.27	1	1,415	Steel, double circuit	4
				1	1,200	–	4
	East 179th Street	138	6.90	2	480	Underground or underwater	–
	Sherman Creek	138	7.81	2	660	Underground or underwater	–
Sherman Creek	East 179th Street	138	1.98	2	715	Underground or underwater	–
Greenwood	Gowanus	138	.64	2	1,000	Underground or underwater	–
	Fox Hills	138	6.36	2	715	Underground or underwater	–
Fox Hills	Fresh Kills	138	7.42	2	785	Underground or underwater	–
Hudson Avenue East	Jamaica	138	10.53	2	675	Underground or underwater	–
	Farragut	138	.37	3	770	Underground or underwater	–
				2	510	Underground or underwater	–
Narrows	Greenwood	138	2.42	2	725	Underground or underwater	–
Bowline Point	Minisceongo[3]	138	.67	2	995	Underground or underwater	–
East 179th Street	Parkchester	138	2.06	4	670	Underground or underwater	–
	Hell Gate	138	4.35	2	475	Underground or underwater	–
				2	715	Underground or underwater	–
Hell Gate	Astoria	138	1.57	2	715	Underground or underwater	–
				2	465	Underground or underwater	–
				2	442	Underground or underwater	–
Astoria	Corona	138	4.84	6	715	Underground or underwater	–
Corona	Jamaica	138	4.49	2	715	Underground or underwater	–

Table II-2:—*Existing Con Edison Transmission Facilities*—Concluded

From	To	Voltage (kV)	Length (mi)	Number of circuits	Summer thermal rating (A)	Principal structure	Number of circuits[1]
Jamaica	Queens/Nassau County line	138	5.64	2	580	Underground or underwater	–
Astoria	Queensbridge	138	2.82	6	715	Underground or underwater	–
Queensbridge	Vernon	138	.73	4	715	Underground or underwater	–
Vernon	Greenwood	138	8.64	2	715	Underground or underwater	–

[1] Number of circuits on common right of way.

[2] Rating is for 2 circuits in parallel.

[3] Jointly owned: Con Edison, 66.67 percent; Orange & Rockland Utilities, Inc., 33.33 percent.

[4] Jointly owned: Con Edison, 85 percent; Orange & Rockland Utilities, Inc., 15 percent, from Ramapo Substation to Rockland/Westchester County line.

INTERCONNECTIONS WITH OTHER SYSTEMS

The Con Edison bulk power system is interconnected to facilities of neighboring utilities, and through them to the entire Northeastern United States east of the Rocky Mountains. Interconnections are located at various points on the periphery of the transmission network described in the previous section. Major points of interconnection are—

(1) Pleasant Valley: This is a major substation in Dutchess County, the northern terminus of Con Edison's transmission network, with 345-kV connections to Niagara Mohawk Power Corp. and Connecticut Light & Power Co., and 115-kV connections to Niagara Mohawk, New York State Electric & Gas Corp., and Central Hudson Gas & Electric Corp. South of Pleasant Valley, but effectively a part of the same interconnection, are 138-kV ties to New York State Electric & Gas Corp. at Mohansic and Carmel.

(2) Ramapo/Ladentown: The Ramapo Substation, in Rockland County, is the major connecting facility at the northwestern extension of Con Edison's transmission system. It has both 500-kV and 345-kV connections to facilities of Public Service Electric & Gas Co. (New Jersey) and 345-kV connections to Central Hudson Gas & Electric Corp. and to Orange & Rockland Utilities, Inc. The connection to Central Hudson Gas & Electric Corp. also connects to the Roseton generating plant. On the route between Ramapo and Con Edison's service area is the Ladentown Substation, the point at which the Bowline Point generating plant is tied in to the Con Edison system.

(3) Farragut: This is a substation on the East River in Brooklyn, from which an underwater 345-kV cable connects to the Hudson Substation of Public Service Electric & Gas Co.[1]

(4) Goethals: This is a substation in Richmond (Staten Island) at the southwestern extreme of Con Edison's transmission network. A 230-kV overhead transmission line connects to the Linden Substation of Public Service Electric & Gas Co.

(5) Jamaica: This point is a substation centrally located in Queens, with connection at 138 kV to the Valley Stream Substation of Long Island Lighting Co.[2]

Table II-3 contains data pertaining to these interconnections.

Interconnections with other systems are used to enhance both reliability and economy of operation. For any power system, strong ties to neighboring systems make for greater resistance to momentary disturbances and offer diverse sources of power for periods of unexpected reduction of the generating capability of that system. Interconnections also increase economy of

[1]The underwater cable from Farragut Substation in Brooklyn to Hudson Power Station in New Jersey was not in service on July 13, 1977, because of failure of a phase shifting transformer at the Farragut Substation. This transformer, originally scheduled for service in May 1972, was damaged during installation and was returned to the manufacturer for repair. Initial service began in Dec. 1972. Other troubles were experienced with this transformer during the intervening period until Sept. 1976, when the transformer failed in service. A new transformer has been ordered. Meanwhile, since October 13, 1977, the cable has been in service with the transformer bypassed.

[2]Another interconnection that played a part in the July 1977 event is a 138-kV underwater connection from Long Island Lighting Co. to the Norwalk Harbor Plant of Connecticut Light & Power Co. The power-exchange capability of this tie was limited in July 1977. Although it is a double-circuit connection, only one circuit was available at that time.

Table II-3.—*Interconnections of Con Edison With Other Systems*

Substations From	Substations To	Interconnected system	Voltage (kV)	Number of circuits	Circuit designation	Power rating[1] (MW) Normal	LTE[2]	STE[3]
Ramapo	Branchburg	Public Service Electric & Gas Co.	500	1	5018	1,000	1,130	1,902
	Waldwick	Public Service Electric & Gas Co.	345	1	J3410	1,612	1,907	2,054
	Rock Tavern	Central Hudson Gas & Electric Corp.	345	1	77	1,510	1,795	1,918
Farragut	Hudson	Public Service Electric & Gas Co.	345	1	B3402	526	628	683
Pleasant Valley	Frost Bridge	Connecticut Light & Power Co.	345	1	398	958	1,096	1,155
	Leeds	Niagara Mohawk Power Corp.	345	2	92	907	1,225	1,316
Goethals	Linden	Public Service Electric & Gas Co.	230	1	A2253	533	708	708
Jamaica	Valley Stream	Long Island Lighting Co.	138	1	901 L&M	264	336	530
Pleasant Valley	Carmel	New York State Electric & Gas Corp.	138	1	16/9826	135	190	238
	Mohansic	New York State Electric & Gas Corp.	138	1	11/9825	135	190	238
	Churchtown	New York State Electric & Gas Corp.	115	1	13	81	109	152
	Hudson	Niagara Mohawk Power Corp.	115	1	12	114	121	149
	Unionville	Niagara Mohawk Power Corp.	115	1	8	97	101	125
	Fishkill Plains	Central Hudson Gas & Electric Corp.	115	1	A6	117	135	151
	Manchester	Central Hudson Gas & Electric Corp.	115	1	M	118	135	228
	Milan	Central Hudson Gas & Electric Corp.	115	1	R10	114	123	150
	Reynolds Hill	Central Hudson Gas & Electric Corp.	115	1	X4	118	135	217

[1] At 0.95 power factor. [2] LTE = long-time emergency rating—3-hour rating. [3] STE = short-time emergency rating—20-minute rating.

operation by allowing for sharing or pooling of reserve capacity and by facilitating the purchase of power, which may be available from other utilities at attractive cost.

Con Edison, like many other urban power systems, is a net "importer" of power for economy reasons. These imports are generally arranged and scheduled in advance under formal agreements. Con Edison imported about 14 percent of its requirements in 1975 and about 23 percent in 1976 under such arrangements.

SPECIAL SYSTEM CHARACTERISTICS

Some of the unusual characteristics of the Con Edison system have already been mentioned: very high load density resulting from population and commercial activity, large daily load variation resulting from the predominance of commercial and residential load, and extensive use of underground transmission facilities.

Another significant characteristic of Con Edison's system is that it is heavily dependent on oil for fuel as are all electric utilities in the coastal areas of the Northeast. The trend to the use of oil accelerated during the late 1960's when reliability considerations led to installation of many oil-burning combustion-turbine generators. The trend was further accelerated in the early 1970's when concern for air quality dictated that use of coal-fired boilers be minimized in urban areas. In connection with this requirement, Con Edison has made formal agreements with the city of New York to take the following steps:

(1) Eliminate the use of coal in the city of New York

(2) Use only fuel with less than 0.37 percent sulfur content

(3) Locate no additional fossil fueled boilers in the city

(4) Develop specific plans and commitments for purchase of power from other systems during air-pollution alerts, so that in-city generation can be reduced during such periods

Dependence on oil has serious cost consequences for Con Edison. For this and other reasons, its rates for electric service are the highest in the Nation. There is, consequently, strong motivation to hold costs down, partly through importation of lower cost power, rather than to generate it with higher cost in-city units.

Finally, the coastal island geography of the Con

Edison service area makes it unusually dependent on use of a limited number of rights of way for its interconnections to external power sources. Even though the power transfer capability of these interconnections may be sufficient, the close physical proximity of multiple transmission circuits occupying these rights of way may increase their vulnerability to outages from severe weather, lighting, and other causes.

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Chapter III

PREVENTION OF BULK-POWER-SUPPLY INTERRUPTIONS

FUNDAMENTAL RELATIONSHIPS

Power supply interruptions range in scale from a blown fuse in a 15-A house circuit to the loss of service over large regions involving millions of customers. Interruptions of electrical service may result simply from accidental disconnections, such as a circuit breaker opening through its own malfunction, or the severing of an underground cable during excavation. Much more often, however, a service interruption results from the proper operation of a protective device in response to abnormal system conditions.

The most common abnormal system condition is excessive electric current. Almost all electrical devices, from home appliances to the largest turbine generators, are endangered by the overheating that results from current flow exceeding a design value. In the case of generating plants, other dangers are overspeeding (which results when a generator is suddenly disconnected from its load) and mechanical shock or vibration (which may result from sudden transient currents caused by disturbances on the electrical network nearby).

By far the most frequent interruptions on a large power system occur at the distribution level: in the very large number of feeder lines and associated transformers that supply residences, commercial areas, and industrial plants. Lightning, ice storms, excavation mishaps, automobile collisions, and other events cause faults or other malfunctions that interrupt service to small areas either momentarily or for periods up to several hours. Less frequently, a disturbance occurs in the bulk power system, which includes the generating plants, high-voltage transmission lines, and large substations. The rest of this chapter is concerned only with prevention of interruptions in bulk power systems.

In general, the prevention of interruptions in bulk power systems depends on three essential elements:

(1) Use of major electrical equipment and control subsystems which are designed for reliability, thoroughly tested, and known from experience to operate reliably over long periods of time

(2) Aggregation and coordination of many automatic protective devices, together with protective operating procedures for cases not amenable to automatic equipment response

(3) Availability of alternate (reserve) power sources and transmission paths to maintain supplies when the normal sources and paths are out of service

COMMON OCCURRENCES AND RESPONSES

The loss, or outage, of one element of a large power system is a very common occurrence. In addition to periods when a generator or other large system element is taken out of service for scheduled maintenance, there are other periods of forced outage resulting from unexpected, and often sudden, malfunction. The public is unaware of most such events, because there is immediate, smooth replacement of the lost function by alternative system capability. Relatively frequently, a lightning stroke causes a transmission line to become momentarily short circuited, or faulted. The normal response to this event is circuit breakers at each end of the line sensing the sudden large current and opening the line, thereby disconnecting it. In most cases, the breakers (by design) attempt to reclose in a fraction of a second and again in several seconds, if the first reclosure is unsuccessful. If, upon reclosure, the fault has cleared and the current is within the safe range, the breaker stays closed and the line stays in service. A brief flickering of lights in areas nearby is the only indication to customers that a disturbance has occurred.

In more serious cases, the fault has not cleared when the breaker recloses, and the breaker opens again, taking the line out of service. Multiplicity of transmission paths is important in this case, because in the short period of time involved, the connected customer load remains the same, as does the power output of generating plants, and the flow of power from plants to connected customers must be redistributed among the various transmission paths that remain. In a large interconnected power system, this redistribution occurs naturally and almost instantaneously (within a few cycles). Following the redistribution, some transmission lines carry more power than before, and if they were carrying power near their design capacity, they may be overloaded after the redistribution. Transmission-line ratings are based primarily on heating; they can carry substantial overloads for short periods of time. They are rated with a normal or continuous capacity, a long-time emergency capacity, and short-time emergency capacity. Lines may be allowed to carry power at long-time emergency ratings for durations up to 4 hours. If long-time emergency ratings are exceeded, system operators must take action to bring the line power flows below such ratings.

Sudden outages occur also at generating plants. In an interconnected system, the lost power is made up by other plants in the total interconnection, in varying amounts at each plant, depending on location and other, technical factors. A very rapid redistribution of power flows occurs also in this case, with accompanying potential for overloads on transmission lines. After the rapid redistribution, system operators and plant operators may be able to effect a more desirable flow distribution by controlling generation at the various plants and by using other control devices on the network.

An outage may occur on a line carrying all, or nearly all, the power output from a particular generator. In this event, the motive power to that generator (steam flow through the turbine) must be reduced to a very low value, or to zero, very rapidly (by automatic devices) to prevent overspeed damage to the unit. Once this is done, with any large steam-turbine generator, the unit cannot be restored to full service immediately, even if the transmission path is restored. The unit must be reconnected to the system under essentially zero load and be brought to full output gradually.

SYSTEM PROTECTION PRACTICES

The normal responses to disturbances, as discussed in the previous section, occur in part as natural physical phenomena resulting from the electrical properties of the network, in part from the action of various control devices, and in part as the result of operator actions. Because the physical phenomena usually transpire within very short time intervals, usually in hundredths of seconds, systems are designed so that protective control functions are performed automatically to the extent practicable. Only the actions that can safely be delayed for minutes or hours are left to human operators.

In a large bulk power system, the arrangement and adjustment of control and protective devices is extremely complex. The design of system protection is a highly developed engineering specialty requiring experience and careful judgment to achieve the optimal arrangement. Each bulk power system is unique in its detailed requirements for protection. The principle, however, is basically simple: it is being able to perform the following functions:

(1) Sense potentially dangerous occurrences anywhere in the system

(2) Disconnect or otherwise protect equipment directly affected

(3) Connect (put into service) other equipment, as required, to maintain the flow of power

(4) Restore the original configuration when the original disturbance no longer exists

Insofar as possible, these operations should be performed automatically. Where automatic responses are not practical, the protection system must provide clear indications to human operators of the actions required.

A problem in system protection is that the protective devices themselves may malfunction. Because the number of such devices is very large, extensive programs of periodic inspection and testing are necessary to minimize improper control operation. Even so, some improper operations will occur. In recognition of this, redundancy, or backup protection, is designed into bulk power systems where it is practical to do so.

COMPLEX TRANSIENT PHENOMENA

Although much of the subject of power system protection can be understood in terms of power output from generators and power flows through transmission lines to load areas, the actual electrical phenomena involved are far more complicated, especially following disturbances, and require complex mathematical expression to be understood and analyzed. Beyond the dangers to uninterrupted service already described, other threats arise because of these more complex electrical phenomena. One such threat results from surges (of voltage or current) through the system following a disturbance. The other major threat is instability.

Surges in an electric power system are analogous to the stresses that propagate through a stiff mechanical structure when it receives a shock at some point. The structure may be damaged by stress appearing far from the point of the original shock. The magnitude of these effects depends on the form of the structure and the relative stiffness and strength of its members. In an electric power network, the connecting members are transmission lines, overhead and underground, and these lines have an electrical "stiffness" that acts to propagate surges of voltage or current. In the case of the electric power network, a surge of voltage, even though it may last for only fractions of a second, may produce voltage at some point that would break down the insulation in a transformer or cable and thereby cause a fault. A surge of current, similarly short in duration, may cause a protective device to trip and to disconnect a major system element needlessly. The possibility of surges is greatest in a system where transmission distances are long, and particularly where underground transmission cable is used extensively.

Instability in an electric power system is a loss of synchronism. In normal operation, all of the rotors of the power generating units connected to a power system are rotating in precise synchronism. Further, the power output and other electrical quantities associated with each generator are absolutely dependent on this synchronous operation. If a generator is subjected to a sufficiently large disturbance, such as one from a nearby fault, it may respond with such sudden relative acceleration as to "pull out" of synchronism, even though the original disturbance is momentary. Once synchronism is lost, the power output of the unit drops rapidly. The unit must be taken off the line, and its speed must then be carefully controlled until the unit is in the precise relationship with the rest of the system to be reconnected in synchronism.

The degree of stability of a bulk power system—its resistance to loss of synchronism in the event of disturbance—can be determined only by lengthy calculation. Qualitatively, however, stability is dependent on holding generation power output and transmission-line flows within safe ranges, on arranging the transmission network to have proper electrical "stiffness," and on having control and protective devices, including generator controls, that act within very short times.

MAJOR EMERGENCIES

The sudden outage of a single element of a bulk power system does not normally result in an interruption of service, because systems are designed to withstand such single contingencies. However, if after one sudden outage, another occurs, the situation may become much more serious. The degree of seriousness depends upon many factors, but primarily upon the effect of the second contingency on system elements that are primary alternative sources or paths for power following the first.

In a major emergency, proper action of both automatic control devices and human operators is essential, if avoidance of a major interruption is to be assured. If there is loss of transmission lines and tripping off of generators, a deficit in power available to serve the load in the area affected may be created. This deficit results in "pulling down" the system frequency from the normal 60 Hz over the entire interconnected area, which in turn causes more power to flow toward the area having the power deficit. Depending on prior flows, this may add to the problem of transmission-line overload. If local-area generation cannot be increased quickly to reduce the deficit, more line outages and tripping off of generators may occur. Eventually, interconnections to adjoining systems may be opened, either by protective devices or by operator action, and the local-area power deficit may be so great that the isolated system will fail completely and shut down.

To avoid complete failure in the absence of rapid increase in local-area generation, it may be necessary that some of the local load be disconnected, or shed. Load shedding can be accomplished either by automatic devices or by operator action. Automatic load-shedding devices operate in response to drops in system frequency, and normally are capable of disconnecting increasing amounts of preselected loads, based on the amount of frequency decline. Manual load shedding by operators can disconnect large areas. The operator's selection of load to be shed can be based on his knowledge of the overall system and the nature of the emergency.

Power systems that are members of formally organized power pools are sometimes required, by pool agreements, to have specified amounts of load-shedding capability, both automatic and manual.[1]

If the load-shedding capability is properly designed and applied, cases of extreme emergency can be survived without complete collapse of the affected bulk power system. Intentionally disconnected areas will be without power for minutes, or even a few hours, but equipment damage will be minimized, and restoration of full service made relatively quickly as the required generating and transmission facilities are put back into service.

[1]Con Edison is a member of the New York Power Pool (NYPP). NYPP requires that each member system provide the facilities to (1) shed a minimum of 25 percent of its load automatically, and (2) relieve at least 50 percent of its load manually within 10 minutes. As a member, Con Edison has both automatic and manual load shedding capability. The automatic feature is designed to operate when there is a generation deficiency and a rapid decline in frequency. The manual system is for use when an interconnected system with a local generation deficiency experiences excessive transmission line overloads, excessively low voltage, or slow decline in frequency. Con Edison has about 48.6 percent of its load relayed for automatic underfrequency load shedding. Alternatively, about one-half of this capability can be operated manually through remote control by the system operator. Con Edison can also reduce its load by about 5.1 percent through manual voltage reduction.

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Chapter IV

THE SEQUENCE OF FAILURE AND RESTORATION

Chapter II describes Con Edison's bulk power system, and chapter III indicates the types of contingencies that arise in such a system and the responses that usually suffice to maintain or restore normal operation. Chapter IV describes the sequence of events of July 13 and 14, 1977, in Con Edison's system, including the incidents of successive failure that in about 1 hour resulted in complete shutdown of the system, and the sequence of actions taken over the 25 hours required to restore service following the shutdown. This chapter is descriptive and without detail. Chapters V and VI present more detailed analyses and conclusions with regard to the failure sequence and restoration sequences.

A simplified system map and a system diagram showing the locations of major facilities are inserted inside the back cover of this report for those who wish to trace the sequence of events and their effects on the system. All substation names and line numbers identified in chapter IV are shown on the inserts.

At 8:35 p.m., just before the first disturbance, the Con Edison system was in normal stable operation, with all in-service elements of the bulk power supply system operating within allowable continuous ratings. Several major elements of the system were out of service for maintenance or repair: transmission line connecting Con Edison to Public Service Electric & Gas Co. (N.J.) and three generating units: Indian Point No. 2, a nuclear unit with operating capability of 873 MW (down because of a pump-seal failure); the 601-MW Bowline Point No. 2 unit (down for boiler repair); and Astoria No. 6, a 775-MW unit owned by the Power Authority of the State of New York (down for turbine repair).

The load on the system was 6,091 MW, below the day's 4 p.m. peak of 7,264 MW, but increasing moderately as waning daylight caused commercial and residential lighting uses to increase.

Of the total system load, 3,891 MW was being supplied by Con Edison's generating plants, and about 2,200 MW was being received over interconnections to adjoining systems. The 2,200 MW of imported power was approximately in accord with the schedule established for that hour by the New York Power Pool (NYPP), and was supplied from generation operated by Central Hudson Gas & Electric Corp., Orange & Rockland Utilities, Inc., Hydro-Electric Power Commission of Ontario, and Quebec Hydro-Electric Commission. Con Edison's generation, along with that of the other major utilities in New York State, was being controlled by automatic economic dispatch[1] from the NYPP control center in Guilderland, New York, about 15 miles west of Albany. At that time, Con Edison's stated operating reserve generation was 2,021 MW, with 738 MW in 10-minute reserve and 1,283 MW in 30-minute reserve. The 10-minute reserve, designed to cover the most severe single contingency (loss of a generator, bus section, transmission line, or transformer), was adequate under NYPP rules, based upon system generation and the power being imported at the time.

From 8:37 p.m. to 9:30 p.m. on July 13, a series of seven incidents occurred, each one in turn either decreasing Con Edison's capability to import power through interconnections, or decreasing its own system generation, or both. The last of the incidents involved the opening of the last remaining interconnection with other systems and left Con Edison as an isolated system having a large deficit in internal generation relative to load. Following isolation, a number of automatic and manual operations were made in an attempt to balance generation and load, but other effects caused system conditions to deteriorate. Various generators were tripped off the line automatically as protective devices responded to highly abnormal conditions, and load could not be reduced quickly enough to establish a stable balance. About 7 minutes after isolation, at approximately 9:36 p.m., the system was completely

[1]Automatic economic dispatch is a poolwide system that in effect operates the New York State bulk power supply as a single system while permitting each member company to retain its corporate identity. During economic dispatch, each hour is divided into shorter dispatch intervals wherein a determination is made of the most economic loading for every available generator. Through this arrangement, generation output ignores company boundaries and permits the exchange of energy among pool members with maximum economy.

inoperative. (Unit No. 13 (25Hz), at the 59th Street Station, was operating but was not connected to the system.)

During the first hour after shutdown, an unsuccessful attempt was made at rapid restoration of the system (reenergizing large parts of the system without fully sectionalizing it into smaller load areas). Concurrently, operating management personnel laid out a step-by-step plan for restoration. The implementation of the step-by-step plan began at 10:45 p.m. and continued through the night and on into the next day. The progress of restoration was considerably slower than anticipated, primarily because the oil pressure required to provide proper insulating properties in underground transmission cables dropped unexpectedly following shutdown, and time was lost in connecting emergency power for pumps. In addition, there was considerable difficulty in starting certain combustion-turbine generators that were identified as "black start" units (units with controls and procedures specifically provided to permit startup without external sources of auxiliary power).

The first significant customer load (74,000 customers) was restored shortly before 2 a.m., July 14. Beginning about 10 a.m., load areas began to be restored rapidly. By 3 p.m., about 50 percent of Con Edison's customers (meters) were reconnected. The restoration was complete 25 hours 46 minutes after shutdown, at 11:22 p.m., July 14.

SEQUENCE OF INCIDENTS

The sequence of incidents that resulted in the collapse of the system was—

(1) At 8:37:17 p.m. (hours:minutes:seconds), a lightning stroke caused a fault on both circuits (W97, W98) of a double-circuit 345-kV transmission line between the Buchanan South and Millwood West Substations. Circuit breakers at Buchanan South opened, but because of a design error in the protective system, a transfer trip signal (to Ladentown) was initiated that opened the 345-kV line from Buchanan South to Ladentown (Y88). Indian Point No. 3, without a transmission path for its output, tripped off the line and shut down. Relaying operation prevented (by protective system design) the normal reclosure of the Buchanan South breakers, leaving W97 and W98 open. Because the Ladentown tie had been carrying 427 MW and Indian Point No. 3 had been generating 883 MW, the result was the total loss of the 1,310 MW of power imported through this connection. Power flow into Con Edison's system from other interconnections immediately increased by 1,265 MW; the remaining deficiency of 45 MW was made up by a slight increase in output of various generators and by a slight drop in load related to a very small drop in system frequency. System conditions were stable following the first incident. One transmission line, a feeder from Pleasant Valley to Millwood West (W81), was carrying power over its normal rating but within its long-term emergency limit.

(2) About 18 minutes after the first incident, at 8:55:53 p.m., another lightning stroke caused simultaneous faults and breaker openings on two more 345-kV transmission circuits: W93/W79 from Buchanan North to Sprain Brook, and W99/W64 from Millwood West to Sprain Brook, both via Eastview. Although these are distinct circuits on the system, they are carried on the same towers from Millwood West to Sprain Brook. The breakers on W99/W64 reclosed and restored the line to service in about 2 seconds. On W93/W79, the breaker at Buchanan North did not reclose; the lightning-induced fault had presumably cleared, but a phase-angle difference had developed across the open breaker contacts exceeding that which would permit reclosure. This was sensed by a protective device (for protecting Indian Point No. 2 from transient surges) that acted by design to prevent reclosure. With the W93/W79 breaker open at Buchanan North, the transmission tie to Ramapo Substation (Y94) was isolated from the Con Edison system. This interconnection had been carrying 1,044 MW before the incident. When flows on other interconnections increased to make up this loss, the W81 line, already overloaded as a result of the first incident, was tripped open by relay operation. Although the W81 line was overloaded, the relay operation was improper, and it was later discovered that the relay involved had a bent contact. After the second incident, Con Edison was in a very serious emergency. About 23 minutes passed with the system apparently stable but with serious overloads on two vital remaining interconnections. (Details of operator action during this critical period are discussed in ch. V.)

(3) At 9:19:11 p.m., the 345-kV line (92) from Niagara Mohawk's Leeds Substation to Con Edison's Pleasant Valley Substation opened, probably because of sagging of the thermally expanded conductors and their resultant contact with a tree. This line was carrying about 1,202 MW at the time. Other lines picked up the load, but became further overloaded as a result.

(4) Following the loss of the interconnection to Leeds, additional events occurred in rapid succession. At 9:19:53 p.m., a transformer at Pleasant Valley was tripped out on overload by a protective relay. This resulted in a loss of 415 MW flowing to Con Edison.

(5) About 2 minutes later, Con Edison's tie to Long Island Lighting Co. (LILCO), from Jamaica to Valley Stream, was opened manually by the LILCO operator. This action, taken in an effort to avert a major emergency on the LILCO system, had the concurrence of the NYPP system operator. Opening this tie reduced power into Con Edison by 520 MW.

(6) About 30 seconds later, at 9:22:47 p.m., an attempt was made to restore one 345-kV transmission line from Pleasant Valley to Millwood West (W81) by closing a breaker at Millwood under supervisory control from the control center. The resulting power surge from the north was too heavy, and the related breaker at Pleasant Valley tripped open. There was no net change in system condition resulting from this incident.

(7) About 7 minutes later, at 9:29:41 p.m., the 230-kV interconnection from Goethals to Linden opened as a result of a failure in the heavily overloaded phase-angle-regulating transformer that was an integral part of this connection. The resulting loss of power to Con Edison was about 1,150 MW. The last remaining tie from Con Edison to external sources, two 138-kV feeders from Pleasant Valley to Millwood East (W11/9825 and W16/9826), tripped immediately from the accompanying power swing.

Following this incident the Con Edison system was isolated, with net load of 5,981 MW and net generation of 4,282 MW. Because of this 28.4 percent generation deficiency, system frequency immediately began to drop. Exact data for the next time period are not available, but it is known that automatic underfrequency load shedding began, and calculations indicate that from 1,440 to 2,200 MW of load was shed within the first 10 seconds after isolation. However, voltage transients occurred during this same period, causing Ravenswood No. 3, carrying 844 MW, to trip off the line. Over the next approximately 4 minutes, output of other generators deteriorated as low frequency affected the output of auxiliary equipment such as feedwater pumps and draft fans. Another large generating unit tripped off the line, and the remaining units followed in rapid succession. By 9:36 p.m., the Con Edison system was completely shut down.

RESTORATION

At time of shutdown, all Con Edison's ties to other systems were disconnected, and a number of circuit breakers on the 345-kV and 138-kV transmission systems were open. All the 60-Hz generators and all but one of the 25-Hz generators were shut down.[2] One 25-Hz generator was operating but was isolated from the main system. All system elements that had been in operation prior to the disturbance were undamaged except the 230-kV Public Service Electric & Gas Co. (N.J.) interconnection from the Goethals Substation to the Linden Station. The phase-angle-regulating transformer in this line had failed (incident 7) and was unavailable for restoration service.

Restoration of large power systems from complete shutdown is a complicated, demanding process. Even if all system elements are ready for service, there are three basic problems to be solved: First, the system or its parts must be synchronized with neighboring systems through interconnections; second, substantial time must be allowed for the large steam-turbine generators to be brought up to full output; and third, as generator output becomes available, it must be matched by gradually increasing the connected customer load, so that an approximate balance of generation and load is maintained. Solution of these problems usually involves "sectionalizing" the system; that is, subdividing it by selective disconnections at various substations so that the balance of increasing load and increasing generation can be effected by carefully timed reconnection of appropriate customer-load sections of the service area.

In the case of the Con Edison shutdown, an attempt at rapid restoration, with very limited sectionalizing, was made. This attempt was begun almost immediately after shutdown. It was unsuccessful because the extent of sectionalizing was not sufficient to prevent overloads on major transmission facilities. Various breakers tripped on overload, or were opened manually by substation operators as they observed indications of damage occurring to transformers and other equipment.

During the same time period, Con Edison operations management met and developed a comprehensive plan for restoration involving full sectionalizing. Briefly, the plan involved reestablishing both the 345- and 138-kV transmission networks with connections to neighboring utilities to the north and east, but initially without load on these networks, so as to provide synchronous energized points to which generators could be connected as they were brought into service. The plan included providing early generation from combustion-turbine generators equipped for starting from complete shutdown, which would supply power needed for bringing additional units into service. As generation increased, sectionalized load areas were to be reconnected in sequence, under central control, to maintain the generation-load balance.

Although a number of unexpected difficulties arose, the plan, begun at about 11:00 p.m., was generally followed. The "black start" combustion-turbine generators did not perform as expected. Loss of oil pressure needed for proper cable insulation resulted in a number of failures in the high-voltage transmission cable networks. As a result, the early parts of the plan took longer to implement than expected; the first significant customer-load pickup did not occur until shortly before

[2]In this condition, the steam valves to the turbine are closed and the generator is electrically inoperative. The unit is kept in slow rotation by turning gear to prevent damage, and lubricant is supplied to bearings, both by use of emergency power supply at the plant.

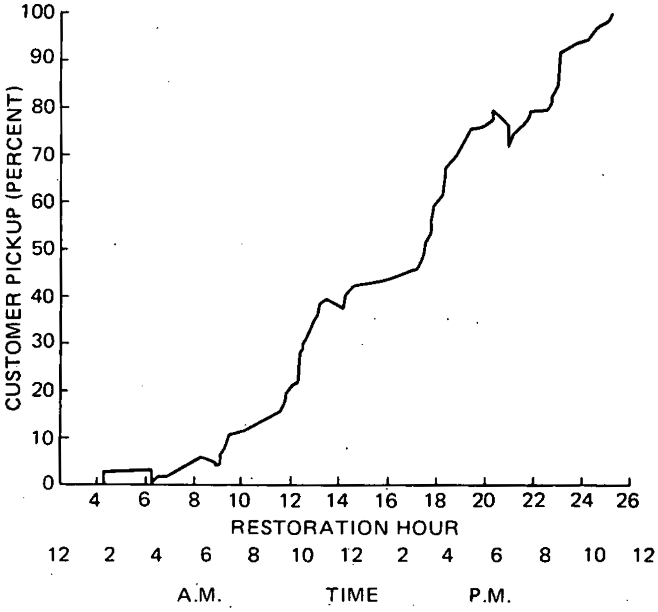


Figure IV-1.—Customer pickup vs. time (from Con Edison analysis) during restoration, July 14, 1977.

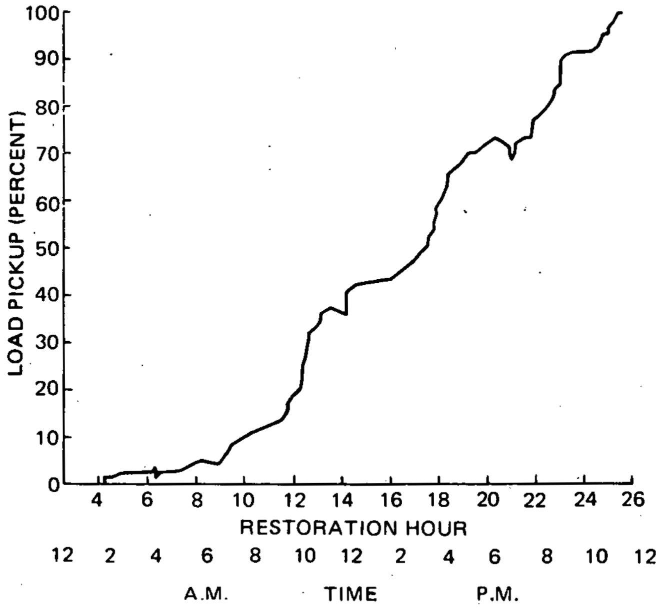


Figure IV-2.—Load pickup vs. time (from Con Edison analysis) during restoration, July 14, 1977.

2 a.m., July 14. Difficulties continued in the transmission network after this time, and it was not until about 10 a.m. when a reasonably smooth sequence of load pickup began. The gradual increase in restoring sectionalizing areas continued through July 14th, and all customer-load areas were restored shortly after 11 p.m.

Figures IV-1 and IV-2 show progress of restoration in terms of percentage of customers and percentage of load from shutdown to complete restoration.

Chapter V

ANALYSIS OF THE JULY 1977 POWER FAILURE

This chapter contains a detailed description of the sequence of events leading to the July 13, 1977, Con Edison power failure, together with technical discussion and conclusions directly related to specific events. Conclusions are given here for completeness; the substance of the conclusions is contained also in chapter VII.

The description and analysis of the events before 9:30 p.m., July 13, 1977, were derived from records obtained and interviews conducted by the staff of the Federal Power Commission (FPC), now of the Federal Energy Regulatory Commission (FERC). The material was obtained from Con Edison, the New York Power Pool (NYPP), the Pennsylvania-New Jersey-Maryland Interconnection (PJM), the Public Service Electric & Gas Co. of New Jersey (PSE&G), and the New England Power Exchange (NEPEX). Quotations from telephone messages during the course of events are taken from transcripts in appendix D. The description of events from 9:29 p.m. to about 9:36 p.m., the period between the isolation of the Con Edison system and its complete shutdown, was gathered from Con Edison plant records and interviews with operating personnel.

The term "Con Edison system,"[1] when referred to in following discussions, means the system that includes the bulk electric power facilities bordered on the north by Putnam County, bordered on the west by the Hudson River, bordered on the east by Connecticut and Queens County, and bordered on the southwest by New Jersey. The Con Edison system, as defined here, incorporates the Power Authority of the State of New York (PASNY) generating unit (Indian Point No. 3) as part of the Con Edison system generation and also includes the PASNY load in the city of New York (about 770 MW at this time) and a small portion of the New York State Electric & Gas Corp. load in Westchester County as part of the Con Edison system load. The system is defined this way to facilitate analyzing the sequence of events by employing a simplified representation of the Con Edison system and the interconnecting ties that were affected by the events. The simplified system map and schematic diagram inside the back cover will be useful in following the sequence of events.

INCIDENT NO. 1

Description

At 8:37:17 p.m. (hour:minute:second), July 13, 1977, two 345-kV lines (designated the W97 and W98 lines) that connect Buchanan South Substation to the Millwood West Substation were each subjected to a phase B fault to ground as a result of a severe lightning stroke. (See fig. V-1.) By design, this event tripped all four circuit breakers of the ring bus at Buchanan South. This action isolated the Indian Point No. 3 generating unit from any load, and the unit tripped off the line for a generation loss of 883 MW. The loss of the ring bus also isolated the 345-kV tie (Y88) to Ladentown, which had been importing 427 MW, for a total loss of 1,310 MW of power previously supplying the Con Edison system load. (See fig. V-1.)

The power flow over the remaining five interconnections responded as shown in table V-1, to replace 1,265 MW of the power supply lost. The remaining deficiency of 45 MW was provided from slight internal generation-governor response and from some load drop that resulted from the frequency decline. System conditions following this incident were stable, with no lines exceeding normal limits except for the W81 345-kV feeder from Pleasant Valley, which was within its long-term emergency rating. However, more than 50 percent of the total Con Edison system load was now being supplied from power sources outside the system.

Discussion

With the existing ring-bus configuration of the Buchanan South bus, a double-circuit outage of the W97 and W98 lines from a lightning-induced back flash automatically trips Indian Point No. 3 off the line and isolates the Y88 Ladentown tie. Normal relay response would have restored the Y88 Ladentown tie and the W97, the W98, or both lines in less than 2 seconds. As a part of the relay scheme at Buchanan South, there is a backup relay circuit, which acts to transfer trip the Y88

[1] Reported Con Edison system loads at specific times may differ from those in other reports if the latter do not include the PASNY and New York State Electric & Gas Corp. loads, included in the system as defined here.

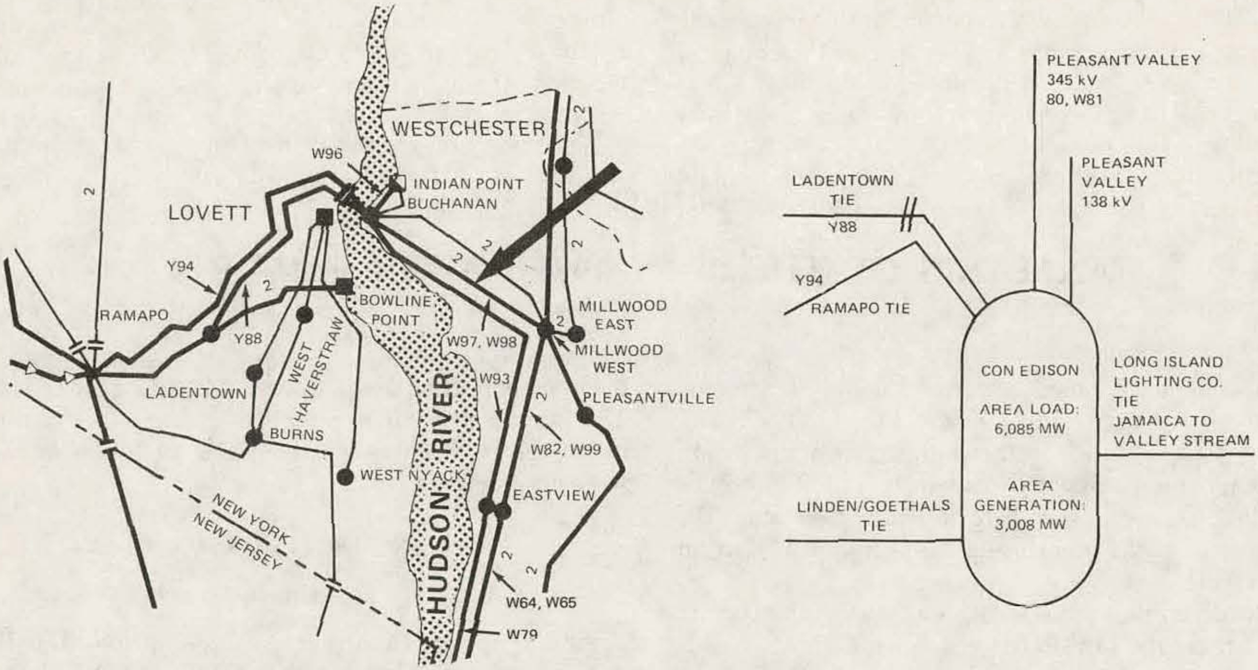


Figure V-1.—Incident No. 1, 8:37:17 p.m. Lightning caused faults on lines W97 and W98. Breakers did not reclose successfully. Indian Point No. 3 generating unit tripped off the line and shut down. Tie to Ladentown, line Y88, was isolated.

Table V-1.—*Interconnection Power Flows Before and After Incident No. 1*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	1,105	1,517	412
Feeders 11 and 16	115	124	9
Line Y94	555	1,148	593
Line Y88	427	0	–427
Jamaica Substation	–267	–232	35
Goethals Substation	304	520	216
Total	2,239	3,077	838
Generation	3,891	3,008	–883
Load	6,130	6,085	–45

breakers at Ladentown if one or more breakers at Buchanan South do not open within 8 cycles after a fault. The arrangement of this circuit inadvertently introduced too large a time-constant delay in the signal that indicated that the breakers had opened. As a result, even though the breakers at Buchanan South operated properly, the time-constant delay in the signal to the transfer trip relay indicated that one or more breakers did not clear fast enough. Consequently, the Ladentown breakers for the Y88 line tripped and locked out, as they are designed to do under such a condition.

Conclusions

The Con Edison system was found to be stable after the loss of the most heavily loaded generating unit (Indian Point No. 3), a major 345-kV tie (Y88), and two major 345-kV feeders (W97 and W98). This fact supports the adequacy of Con Edison's existing design criteria to deal with contingencies that have been considered in system planning studies. However, the following three elements of concern arise from the review of this disturbance:

(1) Logic for the existing Buchanan South bus configuration

(2) Laxity in implementing the NYPP Operating Reserve Policy (OP-2-7)

(3) Design of the Buchanan South backup relay protection scheme

The logic of maintaining separate north and south buses at Buchanan stems from the fact that an attempt to implement a "breaker-and-a-half" configuration that would connect both buses would introduce two undesirable features: (1) higher fault duties on breakers and (2) greater risk of losing both nuclear units (Indian Point Nos. 2 and 3) for a temporary fault on any one of the six 345-kV lines that would be connected to the unified bus. An option to be investigated, however, is the conversion of the Buchanan South bus to the conventional scheme of one breaker on each of the four lines, with a bus-tie breaker added to provide protection against a stuck breaker. This conversion would introduce the additional cost of one breaker and associated disconnects, but it would provide greater reliability. Another option would be to revert to the original design of the Buchanan South ring bus in which the W97 and W98 lines are connected to adjacent segments of the ring bus, in contrast to the existing connections on opposite segments of the ring bus. This would make the outage of both the W97 and W98 lines a credible single contingency and would therefore reduce transfer capability to Con Edison.

Under the existing ring-bus arrangement, a double-circuit fault on the common tower lines (W97 and W98) will trip Indian Point No. 3. With these lines on adjacent segments, Indian Point No. 3 would not have to trip and would be available as a power source as soon as one or both of the lines were restored, normally within seconds. A stuck breaker with the lines connected on adjacent segments would clear the entire Buchanan South bus and would trip Indian Point No. 3. However, this situation would result only from a double contingency.

If Con Edison had more strictly adhered to OP-2-7 before and after this first incident, the system would have been in much more stable condition at the time of the second incident (which occurred about 18 minutes later). For example, OP-2-7 requires that a minimum of one-third of the 10-minute reserve (two-thirds of synchronized 10-minute reserve) must be under Automatic Generation Control (AGC), with at least two units on AGC in each control sub-area. Con Edison did not have any generation on AGC before or after this incident. Therefore, there was no automatic generation response to the 883-MW loss of generation at Indian Point No. 3. Moreover, the manual request for generation increase from the reserve generation was not made by the Con Edison system operator until 8 minutes after the loss occurred. Compounding the effect of this 8-minute delay was the fact that none of the generating plants, except the Arthur Kill steam plant, responded with the rate of increasing generation that the Con Edison system operator expected.

When the Con Edison system operator called for a fast load pickup at 8:45 p.m., he expected in-city generation increases from steam stations and combustion turbines approximately equal to the claimed 10-minute reserve (738 MW). Response from the steam stations as compared with the claimed capability is illustrated in figure V-2. Response from combustion turbines at Astoria was delayed because maintenance crews were inspecting the units and had not reported them as unavailable for 10-minute reserve status. Under the provisions of OP-2-7 the conditions mentioned should have been reported to the Con Edison system operator.

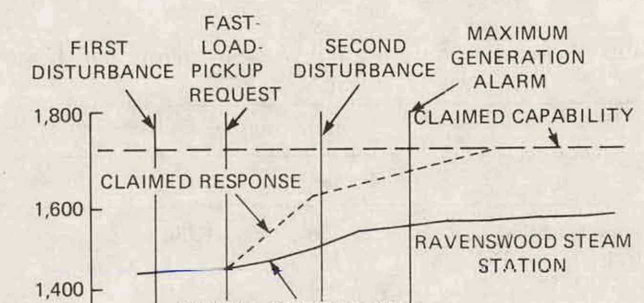


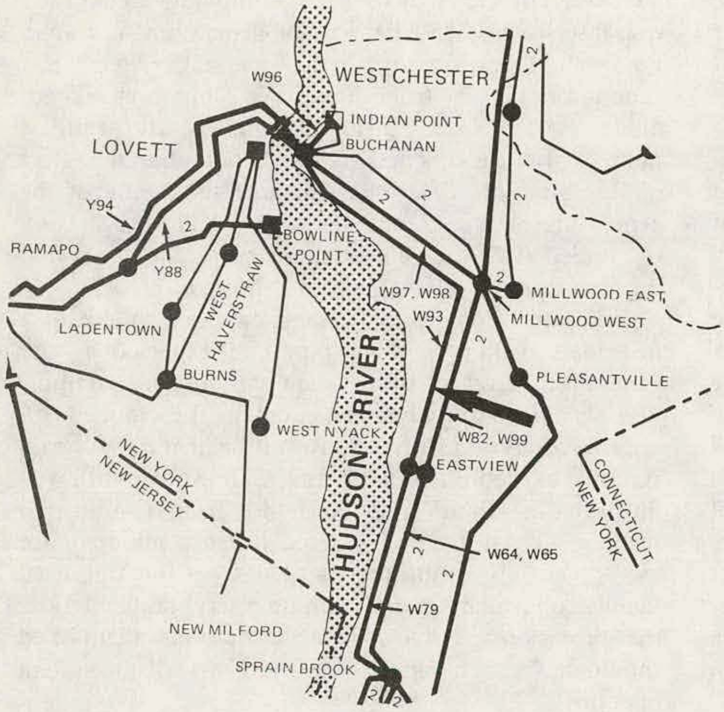
Figure V-2.—Generator station output, July 13, 1977.

INCIDENT NO. 2

Description

At 8:55:53 p.m., about 18½ minutes after the first incident, a severe lightning stroke caused the tripout of two 345-kV lines: W93/W79, which connects the Sprain Brook Substation to the Buchanan North Substation and W99/W64, which connects the Sprain Brook Substation to the Millwood West Substation. (See fig. V-3.) These two 345-kV lines share common towers between Millwood West and Sprain Brook. The W99/W64 line breakers reclosed at both ends and the line was restored to service in about 2 seconds. The W93/W79 line was energized from Sprain Brook, but the line breaker at Buchanan North was designed not to reclose automatically if the phase angle across the No. 11 breaker was greater than 20 degrees. This provision protected the Indian Point No. 2 nuclear unit from potential power surges.

The failure of the No. 11 breaker to reclose isolated the last Con Edison interconnection to the northwest. This Y94 interconnection had been transferring about 1,044 MW to Con Edison at this time. As a result of this major loss of power from the northwest, the power automatically surged in from the north and caused the tripout of the W81 line between Pleasant Valley and Millwood West. Normally, the W81 line would not trip out for this condition. However, Con Edison personnel later discovered that a bent contact on one of the protective relays at Millwood West caused the improper action.



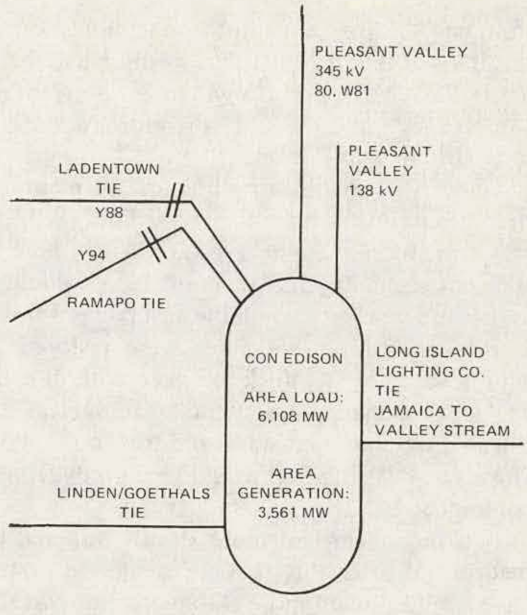


Figure V-3.—Incident No. 2, 8:55:53 p.m. Lightning caused faults on lines W93/W79 and W99/W64. Breakers on W99/W64 successfully reclosed, and the line stayed in service. W93/W79 stayed open at Buchanan North, isolating the Y94 tie to Ramapo. Line W81 tripped out during the resulting power swing because of faulty relay operation.

Discussion

The loss of the last tie to the northwest and the W81 line from the north placed a heavy burden on the remaining ties. (See table V-2.) The 345-kV 80 line was carrying 1,356 MW from Pleasant Valley, and 907 MW was coming from PJM across the Linden/Goethals tie. The normal rating of the 80 line is 825 MW, and the normal rating of the Linden/Goethals tie is 505 MW. The short-time emergency (STE) rating for the 80 line is 1,016 MW, and for the Linden/Goethals tie, 717 MW. It is evident that both facilities were operating much above the maximum allowable power flows, and immediate action was required to correct this condition. Con Edison's operating procedure E0-4032-7 (June 8, 1973) requires that feeder overloads above STE must be reduced within 5 minutes to avoid damage to the feeder or terminal equipment.

The constructive responses available to the Con Edison system operator at this time were—

(1) Load shedding (in Con Edison system)

(2) Rapid increase in Con Edison generation

(3) Load shedding (in Long Island Lighting Co. system) by request of the Con Edison system operator

No attempt to shed load was made until 18 minutes later, when only a 5-percent voltage reduction was initiated. Even if the voltage reduction had been implemented immediately, it would have been inadequate, because it would have contributed only about 150 MW to a 1,200-MW deficiency.

Table V-2.—*Interconnection Power Flows Before and After Incident No. 2*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	1,456	1,356	−100
Feeders 11 and 16	138	284	146
Line Y94	1,044	0	−1,044
Line Y88	0	0	0
Jamaica Substation	−195	0	195
Goethals Substation	277	907	630
Total	2,720	2,547	−173
Generation	3,561	3,561	0
Load	6,281	6,108	−173

Considering the magnitude of the deficiency and the short time required for correction, not much immediate help could be expected from reserve generation. In any event, no request for maximum generation was made until 10 minutes later.

The Jamaica/Valley Stream 138-kV tie between Con Edison and Long Island Lighting Co. was lightly loaded and could have provided about 400 MW of additional help at this time. This could have been accomplished only by increased generation or load reduction on the Long Island Lighting Co. system, because the tie between New England and Long Island was already at maximum allowable loading into Long Island. The NYPP senior pool dispatcher had recognized this potential source of help and had requested the Long

Island Lighting Co. system operator to pick up all the generation available 10 minutes before this second incident occurred. The NYPP senior pool dispatcher reconfirmed his request to Long Island Lighting Co., ". . . get all the generation out that you can get down there," about 9 minutes after the second incident; he could not request load shedding from Long Island Lighting Co. then because Con Edison had not yet shed load or reduced voltage. The NYPP senior pool dispatcher ordered the Con Edison system operator to effect voltage reduction at 9:09 p.m. and was then able to order Long Island Lighting Co. to effect 5-percent voltage reduction a few seconds later. The senior pool dispatcher had requested Con Edison to shed load several times before this order.

Conclusions

None of the three productive options available to the Con Edison system operator were pursued by him in the first 10 minutes following the second incident. The only efforts made were to change taps on the Linden/Goethals phase shifting transformer to reduce loading on this PJM tie, and to request help from the NYPP senior pool dispatcher to unload the 80 line from Pleasant Valley. Both of these lines were heavily overloaded.

It is apparent that the Con Edison system operator was not aware that the Y94 tie between Ramapo and Buchanan North was open. However, even if this tie were closed, any action to reduce loading on the Linden/Goethals tie would have increased, to some degree, the already heavily overloaded 80 line from Pleasant Valley. It should be obvious to a system operator that, for any given number of interconnecting ties, power reduction by phase angle changes in any one tie is reflected by power increases in all other ties by a ratio that depends upon the relative impedances.

Had the Y94 tie to Ramapo been closed, it would have been logical for the Con Edison system operator to ask the senior pool dispatcher for help in unloading the 80 line. Faulty communications between them, however, apparently contributed heavily to the failure. A review of the taped conversations strongly suggests that the Con Edison system operator assumed that the Ramapo/Buchanan tie was closed but was not transferring any load. It also suggests that the senior pool dispatcher was aware that it was open and assumed that the Con Edison system operator knew that it was open. Unfortunately, neither party clearly stated his understanding of this matter.

The knowledge that the Ramapo/Buchanan tie was open was finally communicated to the Con Edison system operator by his chief system operator, who had made this determination in less than a minute while being informed of the situation over the telephone. This information was given to the Con Edison system operator at about 9:08 p.m., 12 minutes after the second incident and 11 minutes before the next incident; so there was ample time to take action that would have prevented the next (third) incident.

Then aware that the Ramapo/Buchanan tie was open, the Con Edison operator recommended to his supervisor, by telephone, that the 80 line be opened to unload the line. The chief system operator told him that he must not open the line but should effect voltage reduction. It appears that the Con Edison system operator might have been confused at this time, because opening the 80 line would have worsened an already critical situation. Moreover, even after being told to reduce voltage, no prompt action was taken.

After another request by the chief system operator about 4 minutes later, the Con Edison system operator began to implement a 5-percent voltage reduction. This action took 5 minutes and was far short of the necessary action required to reduce the serious overloading on the 80 line from Pleasant Valley, or the 92 line from Leeds that was supplying this power to the 80 line at Pleasant Valley. Yet, no load shedding action was implemented during this interval of over 23 minutes following the second incident. However, at 9:18 p.m., 22 minutes after the second incident, the Manhattan/Bronx district operator, at the direction of the system operator, initiated 8 percent voltage reduction.

No meaningful corrective action was taken in the critical 12 minutes before the third incident, because the Con Edison system operator was occupied, talking with his supervisor (chief system operator) over the telephone. Meanwhile, he was unavailable to coordinate corrective actions with key personnel at the pool control center, who were trying to contact him. The Con Edison system operator managed to transfer decisionmaking responsibility to his supervisor, who was in no position to respond adequately, because he was at home and had limited knowledge of the conditions before or during the disturbances. However, while being informed of the situation, the chief system operator was quick to recognize that there was trouble on the Y94 tie feeder from the west. As soon as this conclusion was reached, which was 11 minutes before the third incident, the Con Edison system operator should have called the senior pool dispatcher to find out what was open on this west tie.[2] It should have been obvious that load shedding of at least 500 MW was necessary as soon as it was known that no ties to the west were in service. Meanwhile, the Con Edison system operator continued to inform his supervisor of the conditions at generating plants, of line loadings, and of previous actions—a tedious process, but essential if the decisionmaking responsibility is to

[2]This information could also have been provided to the system operator either directly from his video scope display of Buchanan North Substation or indirectly through the Westchester district operator from his supervisory system for Buchanan.

be transferred to one not so informed. It should be noted that the decision of the system operator to call his supervisor was purely discretionary. The operating procedures of Con Edison permit but do not require the system operator to contact his supervisor in times of system emergency.

The transfer of decisionmaking responsibility should not be allowed when power system facilities are being subjected to loads above their short-time emergency ratings. The supervisor in charge and on duty must be responsible and capable of assuming such responsibility.

INCIDENT NO. 3

Description

At 9:19:11 p.m., a 345-kV line, 92, from Niagara Mohawk's Leeds Substation to Con Edison's Pleasant Valley Substation tripped out as a result of a phase B fault to ground. (See fig. V-4.) The fault was probably caused by line sag to a tree because of the excessive overload imposed on the line during the previous interval of over 23 minutes. The exact cause of the fault could not be confirmed, because the location of the fault could not be identified, despite extensive efforts.

This last 345-kV source of power from the north was supplying about 1,202 MW at the time of the trip. As table V-3 indicates, 419 MW was supplied to the 80 line through the S1 transformer at Pleasant Valley, which connects the 345-kV bus and the 138-kV bus at that location. The remaining 783 MW loss was primarily replaced by increasing power flows from PJM through the Linden/Goethals tie and from Long Island Lighting Co. through the Jamaica/Valley Stream tie.

The Linden/Goethals tie, which had been returned to within normal transfer ratings by tap changes on the phase-angle-regulating transformer, was again subjected

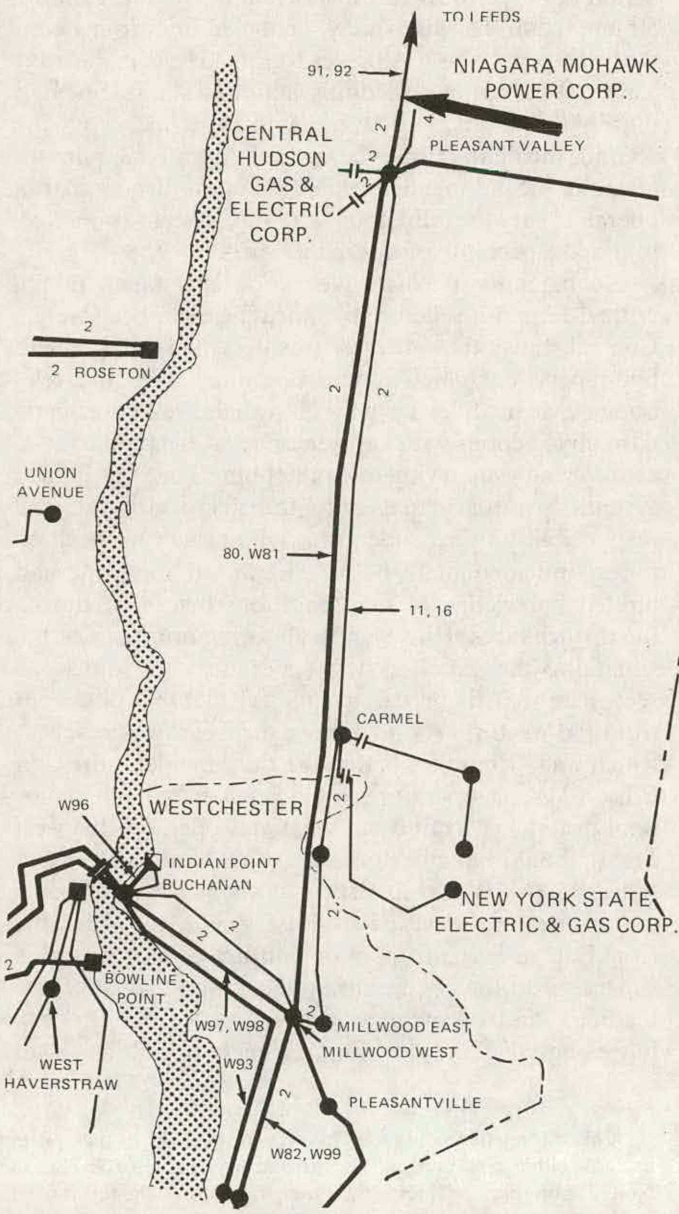


Table V-3.—*Interconnection Power Flows Before and After Incident No. 3*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	1,202	419	–783
Feeders 11 and 16	249	253	4
Line Y94	0	0	0
Line Y88	0	0	0
Jamaica Substation	48	255	207
Goethals Substation	450	980	530
Total	1,949	1,907	–42
Generation	4,146	4,146	0
Load	6,095	6,053	–42

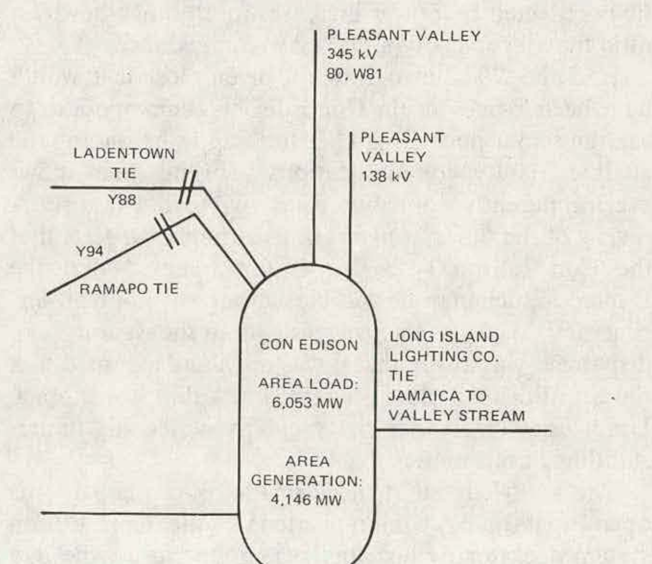


Figure V-4.—Incident No. 3, 9:19:11 p.m. Line 92 faulted to ground and tripped.

to loads (980 MW) in excess of normal (505 MW) and short-term emergency (717 MW) ratings. The Con Edison system now had only four remaining points of interconnection from which to import the 1,900 MW (approximately) of load not being supplied by generation within the Con Edison system.

Discussion

Because both the 92 and 80 lines had been subjected to loadings substantially in excess of their short-time emergency ratings for over 20 minutes, it is not surprising that one of the lines finally failed. That the Con Edison system operator, the NYPP senior pool dispatcher, and the Niagara Mohawk Eastern Division dispatcher would tolerate this known condition for so long without taking actions to obtain relief is difficult to understand. Such specific action should have been (1) loading shedding or (2) manually tripping the line out of service to prevent the hazard of line sag.

Conclusion

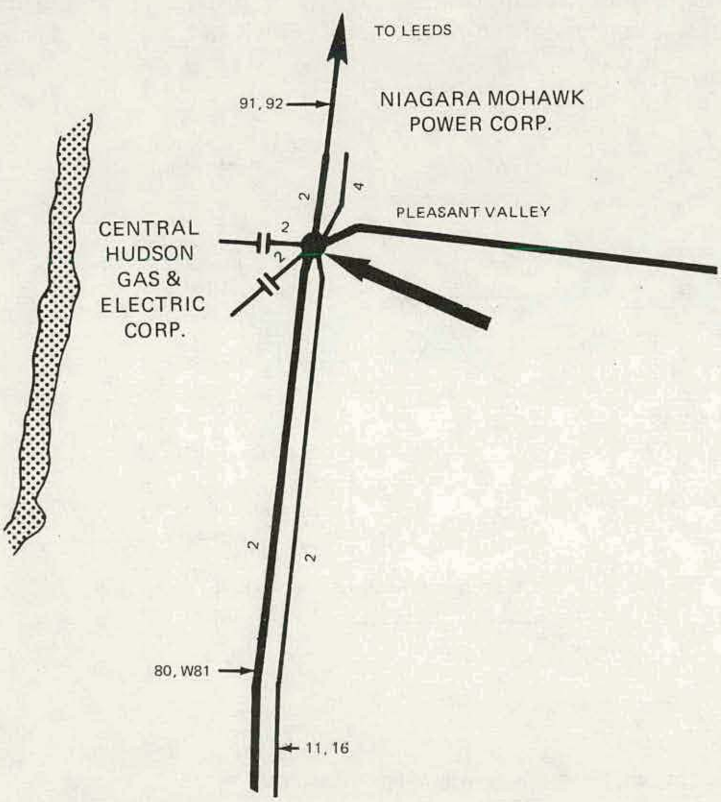
During periods of power system stress, careful attention must be given to ratings of facilities. High power surges through a given facility that is above its short-time emergency rating but below the lowest fault-current exposure may be tolerated for no more than 1 to 3 minutes, depending on the nature of the equipment. It may be desirable to install overcurrent protection on such facilities to provide backup protection when manual response is not properly implemented. The knowledge that an overcurrent device is installed that will trip a given facility (such as the 80 line) in 5 minutes if the loading is above the short-time emergency rating would, perhaps, motivate the operator to take action immediately. More important, it would motivate the operator to take preventive action to avoid the system condition creating the overload.

INCIDENT NO. 4

Description

At 9:19:53 p.m., the 345-kV/138-kV transformer at Pleasant Valley tripped out because of an overload. (See fig. V-5.) This transformer (S1) was tripped out by an overcurrent relay after being subjected to an overload for about 40 seconds, resulting from the loss of the 92 line. The S1 bank was supplying about 415 MW to the 345-kV 80 line at the time of the trip.

This loss of 415 MW of supply to the Con Edison system was replaced by increased power flow over the remaining three interconnections. (See table V-4.) The Linden/Goethals tie was now loaded (1,090 MW) well above its short-time emergency rating (717 MW). The Jamaica/Valley Stream tie to Long Island increased to 310 MW, which is less than the long-time emergency rating of the tie. However, the Long Island tie to New England (Northport/Norwalk tie) increased to 340 MW, which is well above the short-time emergency rating (250 MW).



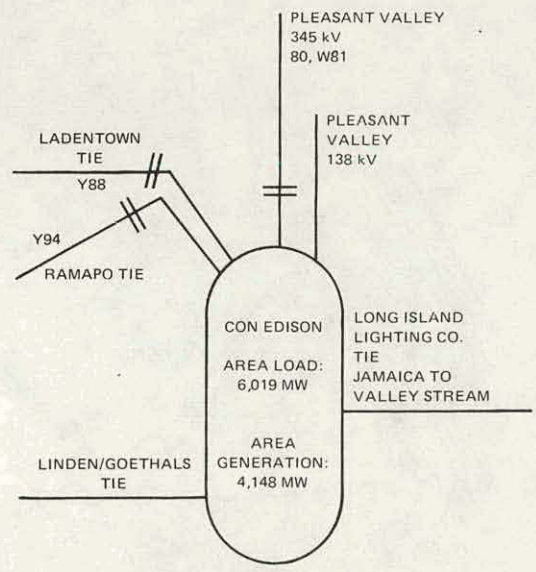


Figure V-5.—Incident No. 4, 9:19:53 p.m. The S1 transformer (345 kV/138 kV) at Pleasant Valley tripped on overload resulting from the loss of the 92 line. (It is necessary to refer to the schematic inside the back cover to understand this effect.)

Table V-4.—*Interconnection Power Flows Before and After Incident No. 4*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	415	0	–415
Feeders 11 and 16	291	471	180
Line Y94	0	0	0
Line Y88	0	0	0
Jamaica Substation	248	310	62
Goethals Substation	920	1,090	170
Total	1,874	1,871	–3
Generation	4,148	4,148	0
Load	6,022	6,019	–3

Discussion

Many factors were affecting the power flow on the Jamaica/Valley Stream tie at this time. Voltage reduction was in progress at Con Edison and in Long Island Lighting Co. Tap changing of the Linden/Goethals phase shifting transformer and increases in generation on the Con Edison and Long Island Lighting Co. systems were also in progress. As related to the Jamaica/Valley Stream tie, some actions were neutralizing the effects of the other actions. For example, load shedding in the Long Island Lighting Co. system would have a tendency to increase power flow through this tie, but voltage reduction at Con Edison would tend to reduce the power flow. It was, in fact, then becoming difficult to assess the effect of the actions. Meanwhile, the Con Edison system operator was trying to inform his supervisor (by telephone) of the dynamic system conditions, a very difficult task. Moreover, the senior pool dispatcher at the power control center did not know what the Con Edison system operator was doing, nor did the Long Island Lighting Co. system operator know what actions were in progress. Both were trying to contact the Con Edison system operator to coordinate their actions with him but were unable to do so.

Conclusion

The tripping of the S1 bank (incident No. 4) was a normal consequence following thc loss of the 92 line (incident No. 3). It was fortunate (and prudent) that the S1 bank was protected for overload, because this facility could well have suffered serious damage. During this period the Con Edison system operator spent most of his time informing his supervisor of the Con Edison system conditions. It might have been more productive if he had spent his time informing the senior pool dispatcher of these conditions, because the supervisor did not have the bulk of information at the disposal of the senior pool dispatcher.

INCIDENT NO. 5

Description

At 9:22:11 p.m., the Jamaica/Valley Stream tie opened while loaded at about 520 MW to Con Edison. (See fig. V-6.) This tie was opened manually by the Long Island Lighting Co. system operator after obtaining the approval of the pool dispatcher. Indicating meters at the pool control center and the Long Island

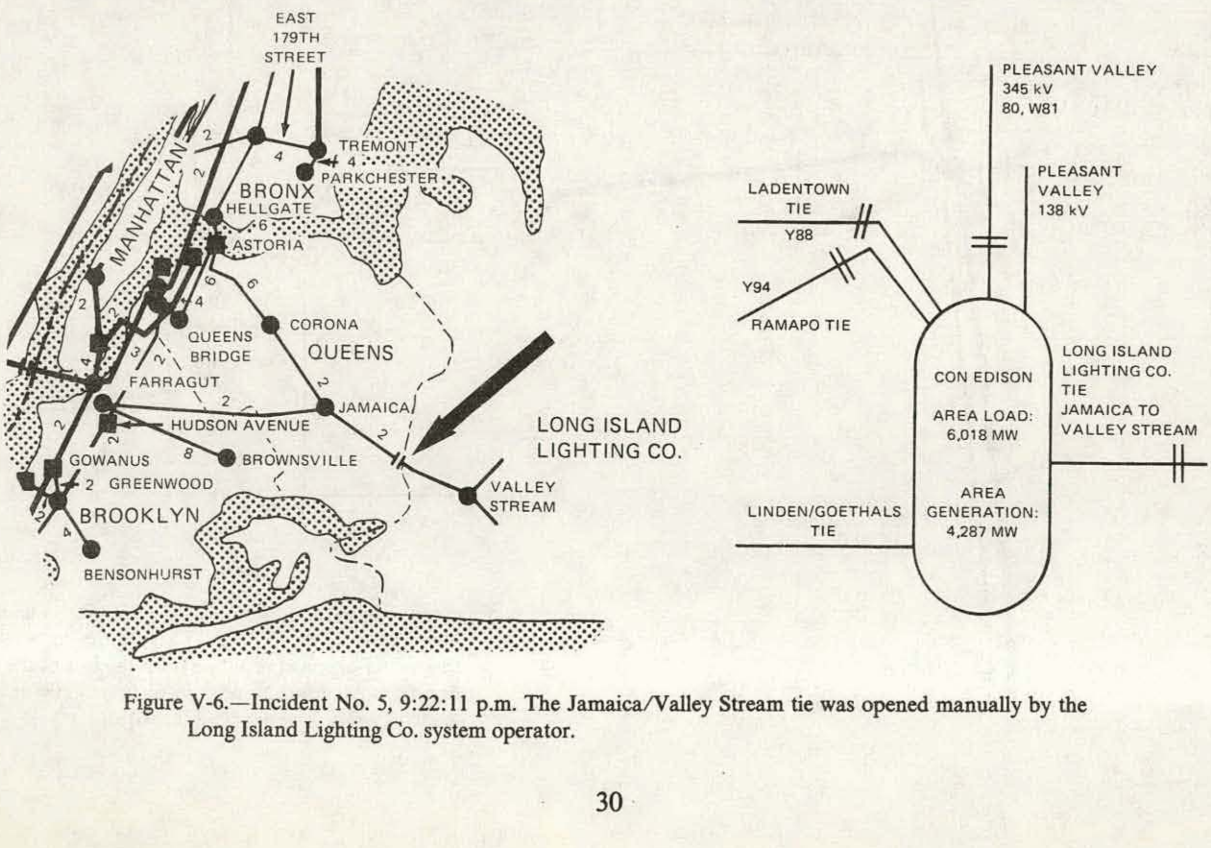


Figure V-6.—Incident No. 5, 9:22:11 p.m. The Jamaica/Valley Stream tie was opened manually by the Long Island Lighting Co. system operator.

Lighting Co. control center were off scale; both have a range of 500 MW.

This 520 MW loss of power supply to Con Edison was essentially replaced by increased power flow over the two remaining ties, both of which were well above their short-time emergency ratings. No significant reduction in Con Edison load occurred up to this point. (See table V-5.)

Discussion

The mutual decision by the pool dispatcher and the Long Island Lighting Co. system operator to open the Jamaica/Valley Stream tie was prudent, according to the information available at the time. Neither party was able to contact the Con Edison system operator during the preceding 15 minutes. Requests by the senior pool dispatcher to the Con Edison power dispatcher to shed at least 600 MW received an affirmative verbal response, yet no evidence of load shedding materialized. A period of 45 minutes had elapsed since the initial Con Edison system disturbance, and rather than showing improvement, the Con Edison system conditions continued to deteriorate. Evidence strongly suggested the possibility that the Long Island Lighting Co. system would go down with the Con Edison system.

Conclusions

In retrospect, it might be reasoned that had Con Edison managed to shed at least 600 MW within the next few minutes, Long Island Lighting Co. could have provided more support to Con Edison by opening the Northport/Norwalk tie. At the instant of separation, Long Island Lighting Co. was generating about 335 MW more than its load (which had been reduced by load shedding). Therefore, the Jamaica/Valley Stream tie would have reduced in flow from 500 MW to 335 MW rather than to zero, as actually occurred.

It should be stressed that the alternative action of opening the Northport/Norwalk tie rather than the Jamaica/Valley Stream tie would have been effective only if Con Edison had managed to shed at least 600 MW within a few minutes. Without this load shedding (which did not occur) the remaining Con Edison ties would still have been over the short-time emergency ratings, and Long Island Lighting Co. would have been exposed to a system collapse.

Table V-5.—*Interconnection Power Flows Before and After Incident No. 5*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	0	0	0
Feeders 11 and 16	395	521	126
Line Y94	0	0	0
Line Y88	0	0	0
Jamaica Substation	520	0	–520
Goethals Substation	860	1,210	350
Total	1,775	1,731	–44
Generation	4,287	4,287	0
Load	6,062	6,018	–44

INCIDENT NO. 6

Description

At 9:22:47 p.m., about 30 seconds after the loss of the Jamaica/Valley Stream tie, an attempt was made to restore the 345-kV source from Pleasant Valley. (See fig. V-7.) Because the W81 line was energized from Pleasant Valley to Millwood, the No. 6 breaker at Millwood was closed via supervisory control. The power surge was too heavy, however, and the RNS2 breaker at Pleasant Valley tripped.

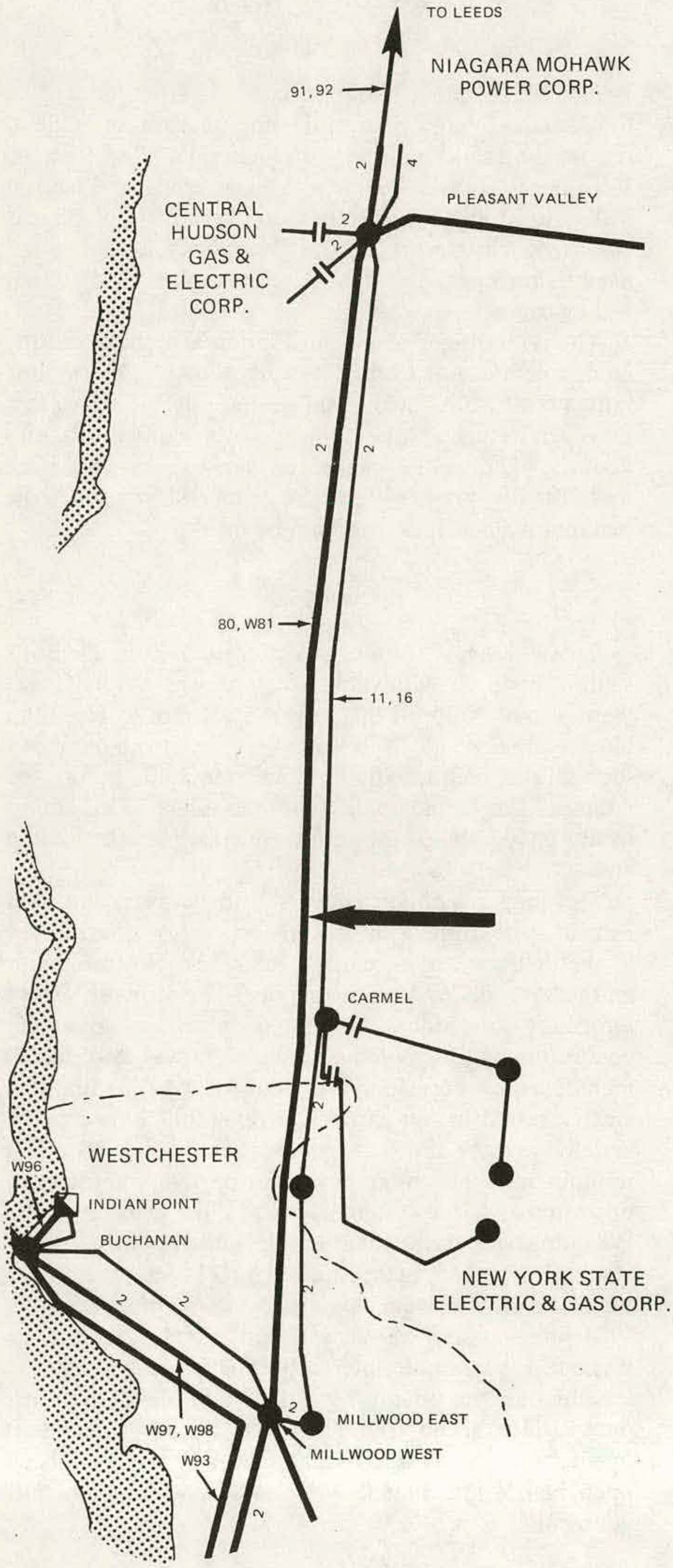
The recording charts from Linden/Goethals and the computer output from Pleasant Valley 138-kV line indicate the power swings shown in table V-6. Both ties, however, returned to original values almost instantaneously. The actual power swings on the ties were undoubtedly greater than the values shown, but the instantaneous values could not be measured.

Discussion

Because the W81 line was energized from Pleasant Valley down to Millwood West, it was evident that there was no fault on this line. An attempt to close the No. 6 breaker at Millwood West might have been successful if such an attempt had been made before the failure of the 92 line about 3 minutes earlier. This action would have reduced the serious overload on the 92 line and avoided its loss.

The long telephone conversation between the Con Edison system operator and his supervisor contributed to the delay in any attempt to close the No. 6 breaker and restore the W81 line to service. The difficult task of informing someone over the telephone of dynamic conditions on a complex power system was destined to include some confusion. The status of the W81 line was clearly stated in the earlier conversations between the system operator and his supervisor. However, about $7\frac{1}{2}$ minutes into the phone conversation, the chief system operator asked the system operator if the loading on the W81 line was decreasing at all. The system operator responded with: "Yeah, I'm down to 1,286." From that time, the chief system operator was assuming that the W81 line was seriously overloaded and that the 80 line was out. Five minutes later, after the 92 line tripped out, the chief system operator was told that line 80 had just opened. He asked if it had been the W81 line that opened and was assured that the W81 line had been open before and that it was the 80 line that had just gone out.

The chief system operator immediately ordered the attempt to reclose the 80 and W81 lines. After 30 seconds, the chief system operator asked if there was any flow in either the 80 or W81 lines. On being told that there still was none, he ordered load shedding. The chief system operator, finally recognizing the full impact of the situation at 9:20 p.m., ordered meaningful responses at that time. However, the attempt to close the W81 line did not occur until 2½ minutes later, nor was any attempt to shed load made until almost 4 minutes after this order. Moreover, when the attempt to shed the 4-kV load was made during the next critical 6 minutes, no effective load reduction was evident.



Conclusion

It appears that by this time the Con Edison system operator was very confused. It is likely that he knew how to follow the relatively routine load shedding procedure, which is clearly defined on page 22 of the manual "Procedure for System Load Management," of the system operating department. Yet, when he was requested to shed the 4-kV load, he responded: "But Charlie, on the 4 kV, where can I cut it out?"

In regard to the unsuccessful attempt to shed the

Table V-6.—*Interconnection Power Flows Before and After Incident No. 6*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	0	304	304
Feeders 11 and 16	550	516	–34
Line Y94	0	0	0
Line Y88	0	0	0
Jamaica Substation	0	0	0
Goethals Substation	1,190	920	–270
Total	1,740	1,740	0
Generation	4,302	4,302	0
Load	6,042	6,042	0

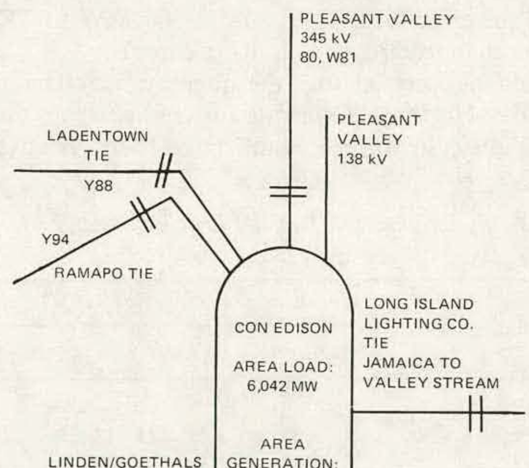


Figure V-7.—Incident No. 6, 9:22:47 p.m. An attempt was made to restore the 345-kV line W81 from Pleasant Valley to Millwood. The line tripped out again from the power swing.

4-kV load, it appears that the Con Edison system operator inadvertently turned the master control switch to the "Frequency Control" position instead of the "Trip/Reclose" position. With this erroneous operation, any attempt to press the "Area Trip" pushbutton at a given station would not be effective. This conclusion is supported by the statement of the Con Edison system operator to his supervisor when he said: "It won't trip the son of a gun, Elmsford," and, again, 22 seconds later when he said: "It won't trip the breakers . . . the area trip." Under the stress of the critical situation, it may be that he inadvertently turned the master control switch to the left, instead of to the right.

The existing voltage-reduction and load-shedding controls are desirable in that they provide great flexibility for selective action related to specific local problems. However, in addition to the existing controls, a simple scheme for load-shedding control should be included that would shed large blocks of load by two buttons to be employed during such bulk power deficiencies as the ones that occurred on July 13, 1977. One button could be used to shed large blocks of load, but it would have a higher exposure of inadvertent operation.

INCIDENT NO. 7

Description

At 9:29:41 p.m., the tap-changing mechanism failed on the Goethals phase-angle-regulating transformer. (See fig. V-8.) This incident tripped and opened the Linden/Goethals tie to PJM while it was delivering 1,150 MW of power to Con Edison. The total generation deficiency (1,680 MW) on the Con Edison system was imposed on the last remaining tie between Con Edison and external power sources: two 138-kV feeders from Pleasant Valley. These feeders (feeders 11 and 16) immediately tripped from the severe overload and isolated the Con Edison system. (See table V-7.)

Discussion

The phase-angle-regulating transformer had been subjected to continuous remote tap changing in an effort to reduce the severe overload on this facility. Remote tap changing while under the existing severe overloads probably contributed to the failure of the tap-changing mechanism. Fortunately, damage to the tap-changing mechanism was repairable in a few days. Had the facility continued to be subjected to the extreme overloads, it probably would have failed within a few minutes and could have suffered more serious damage that may have required months for repair or replacement.

Table V-7.—*Interconnection Power Flows Before and After Incident No. 7*

Location	Interconnection flows (MW)		
	Before	After	Change
Lines 80 and W81	0	0	0
Feeders 11 and 16	536	0	-536
Line Y94	0	0	0
Line Y88	0	0	0
Jamaica Substation	0	0	0
Goethals Substation	1,150	0	-1,150
Total	1,686	0	-1,686
Generation	4,251	4,282	31
Load	5,937	5,981	44

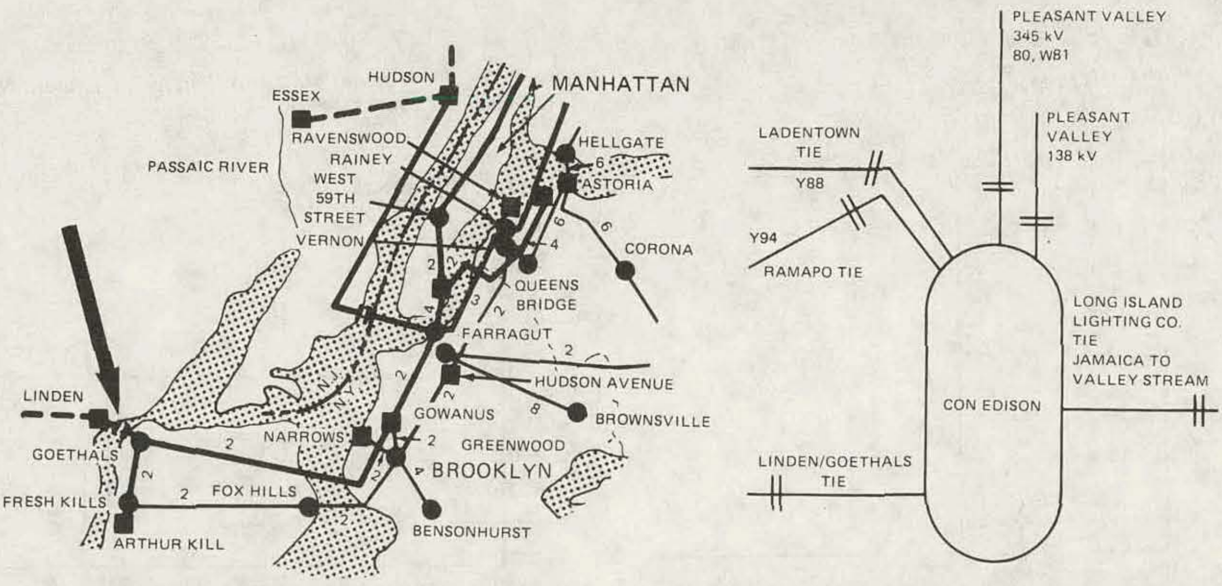


Figure V-8.—Incident No. 7, 9:29:41 p.m. The tap-changing mechanism on the phase-angle-regulating transformer in the Linden/Goethals interconnection failed, tripping the tie. The 138-kV feeders (11 and 16) from Pleasant Valley immediately tripped on overload. The Con Edison system was isolated.

Conclusion

Expensive or critical facilities, such as the Goethals phase-angle-regulating transformer, should not be subjected to loads in excess of prudently established short-time emergency ratings. Automatic protective devices should be installed on all such facilities to prevent damage from severe overloading.

PLOTS OF MAJOR TRANSMISSION-LINE FLOWS AND BUS VOLTAGE VARIATIONS, JULY 13, 1977

Figures V-9 through V-18 are plots of major transmission line flows during the time period of interest. Figures V-19 through V-22 display 345-kV bus voltage variations. These data were obtained from the disturbance file for all NYPP member systems that is telemetered at 1-minute intervals to the NYPP control center in Guilderland, N.Y.

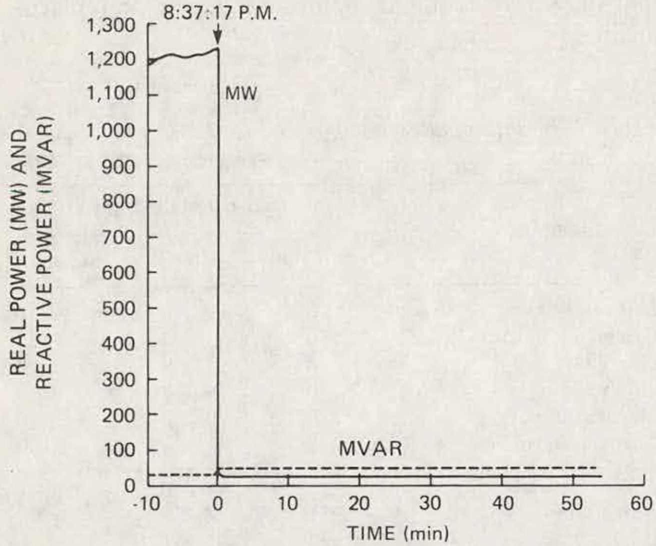


Figure V-9.—Total 345-kV line flows, Buchanan South to Millwood West (W97 and W98), July 13, 1977.

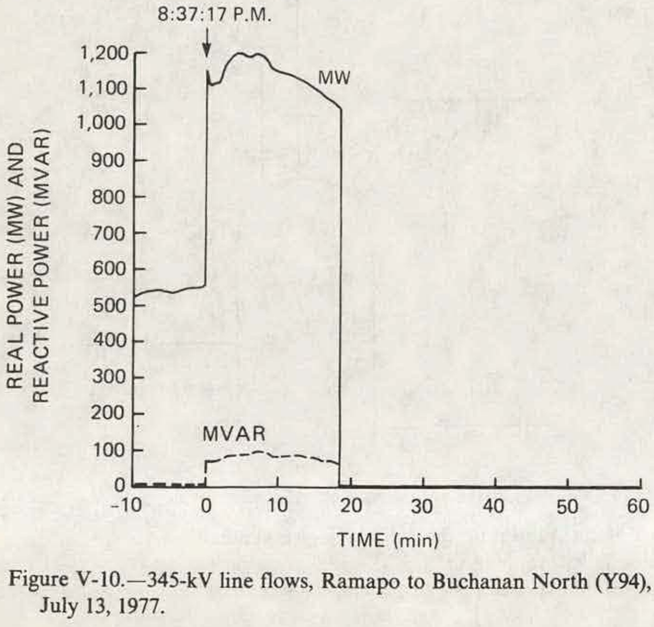


Figure V-10.—345-kV line flows, Ramapo to Buchanan North (Y94), July 13, 1977.

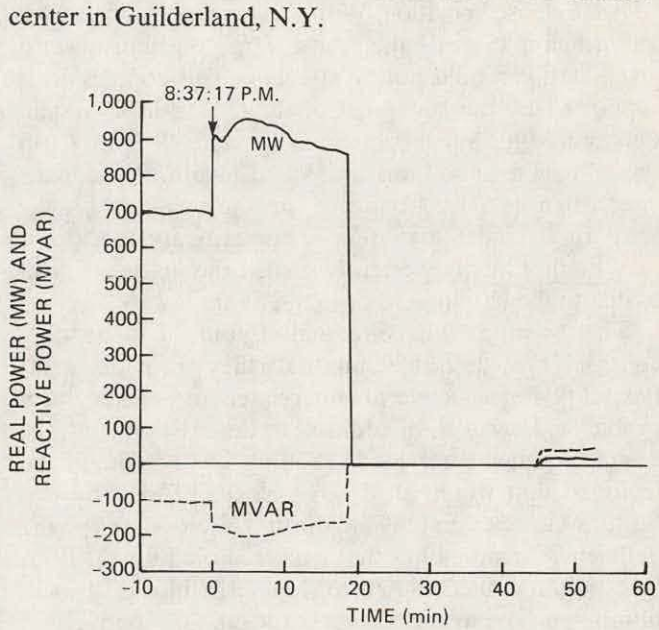


Figure V-11.—345-kV line flows, Pleasant Valley North to Millwood West (W81), July 13, 1977.

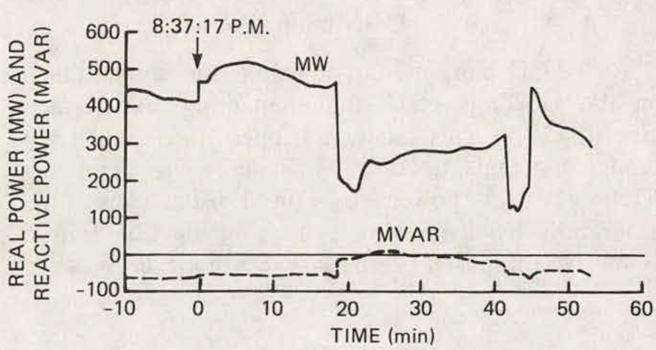


Figure V-12.—345-kV line flows, Frost Bridge to Pleasant Valley North (line 398), July 13, 1977.

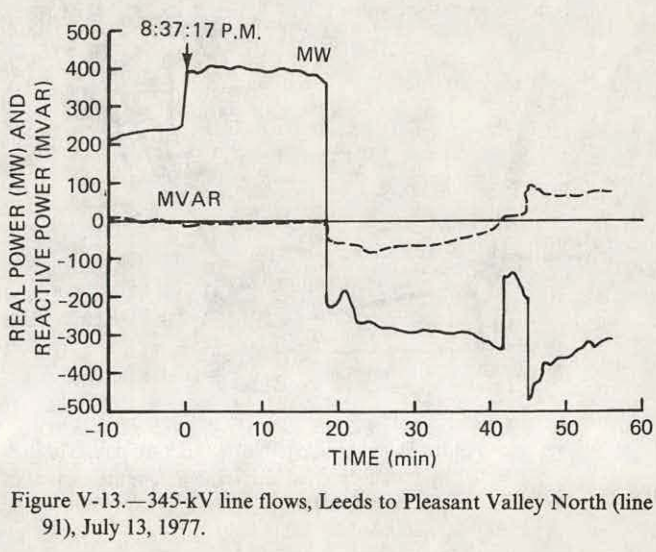


Figure V-13.—345-kV line flows, Leeds to Pleasant Valley North (line 91), July 13, 1977.

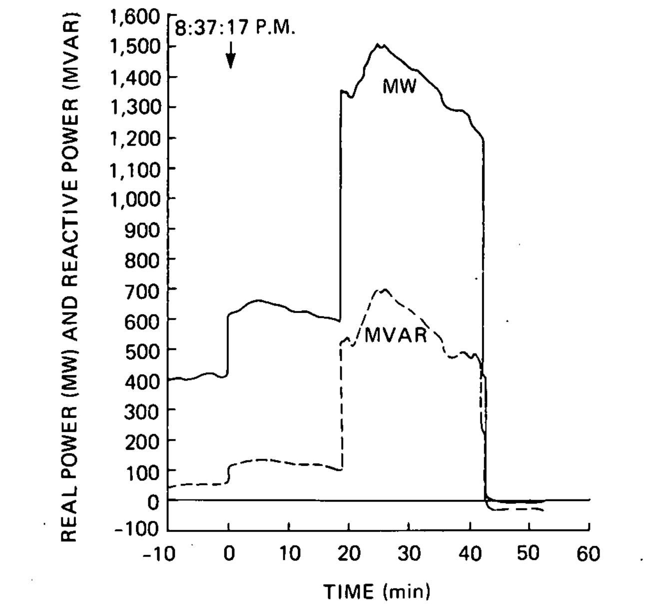


Figure V-14.—345-kV line flows, Pleasant Valley South to Millwood West (80), July 13, 1977.

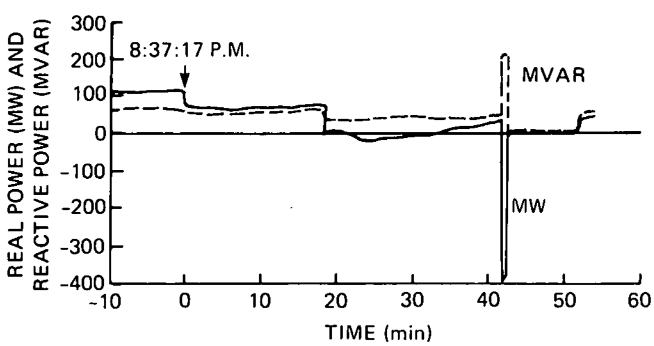


Figure V-15.—Power flows, SI 345-kV/138-kV transformer to Pleasant Valley South bus, July 13, 1977.

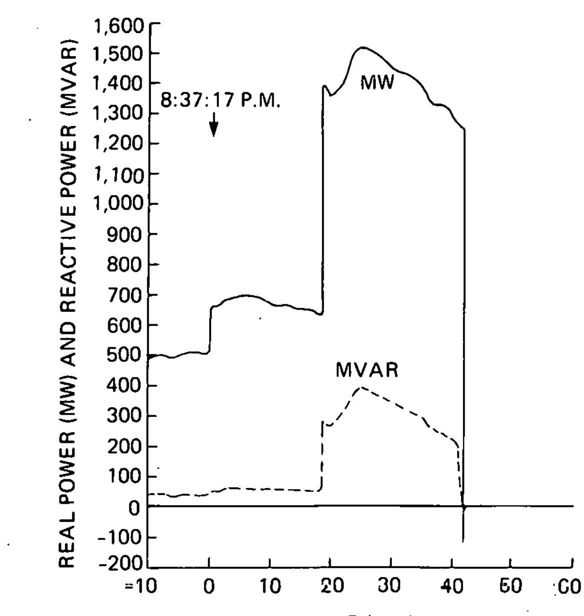


Figure V-16.—345-kV line flows, Leeds to Pleasant Valley South (92), July 13, 1977.

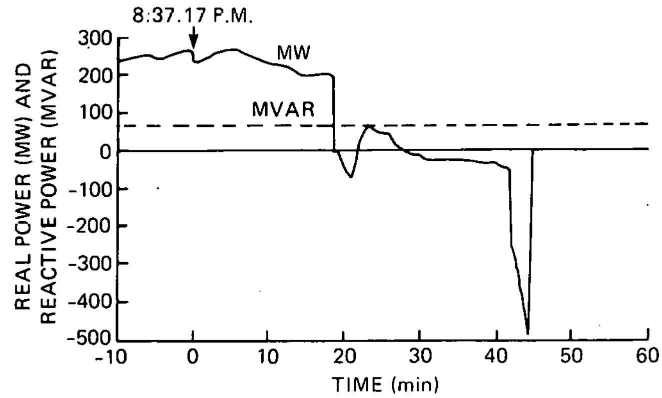


Figure V-17.—138-kV line flows, Jamaica to Valley Stream (901L&M), July 13, 1977.

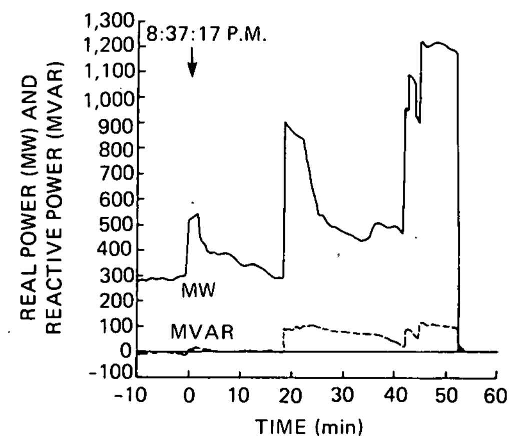


Figure V-18.—230-kV line flows, Linden to Goethals (A2253), July 13, 1977.

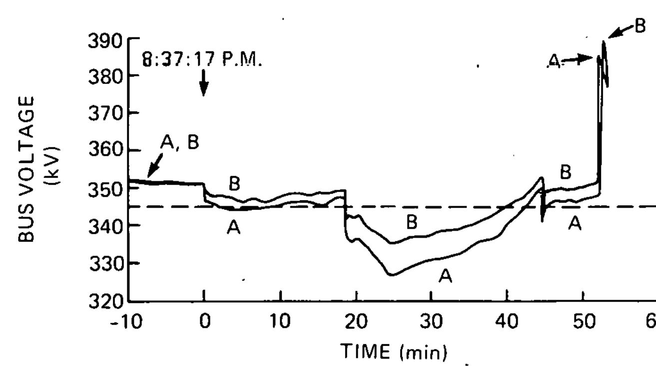


Figure V-19.—345-kV bus voltages, July 13, 1977. A: Millwood West. B: Sprain Brook.

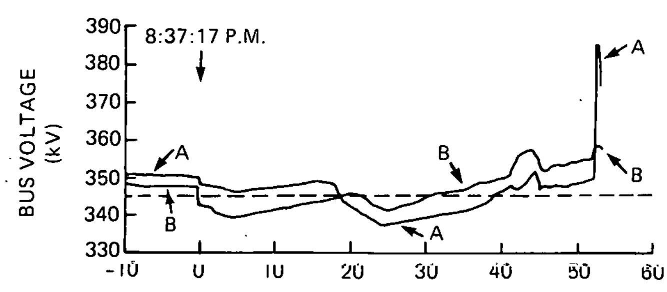


Figure V-20.—345-kV bus voltages, July 13, 1977. A: Goethals. B: Pleasant Valley.

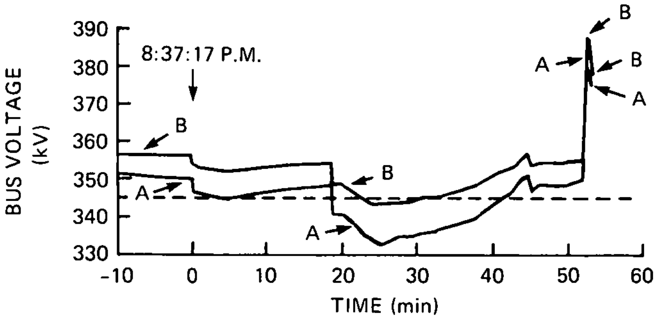


Figure V-21.—345-kV bus voltages, July 13, 1977. A: Dunwoodie. B: Gowanus.

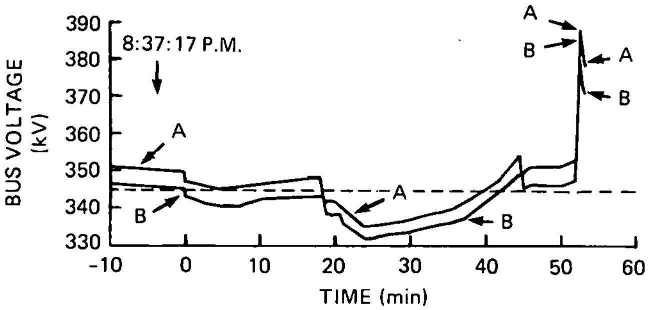


Figure V-22.—345-kV bus voltages, July 13, 1977. A: Rainey. B: Farragut.

EVENTS AFTER ISOLATION

After isolation of the Con Edison system, changes in system frequency and voltage occurred very rapidly. A detailed record of conditions, similar to the one that was used to analyze events during the prior time period, is not available. The information on the period from isolation to shutdown has been obtained from Con Edison's own analyses, which consist of analyses of frequency charts at certain power stations, together with limited computer simulation of the isolated system. The FERC staff also made a limited simulation, which confirmed Con Edison's results.

After the fault in the Con Edison's Goethals to Linden (Public Service Electric & Gas Co.) 230-kV phase-angle-regulating transformer and subsequent separation of the Con Edison system from the eastern United States interconnected power system, frequency dropped rapidly in the island area because of a large imbalance between island generation and load. Con Edison's island load was 5,981 MW (net) and island generation was 4,282 MW (net), a generation deficiency of 1,699 MW, or 28.4 percent. A graph of system frequency, obtained by Con Edison from spectral analysis of the energy control center tape record, is shown in figure V-23.

The exact frequency response during the first 10 seconds of isolation is not known because of the absence of data from high-speed instrumentation, but results from the two computer simulations and audio tape analysis correlate reasonably well. The simulations

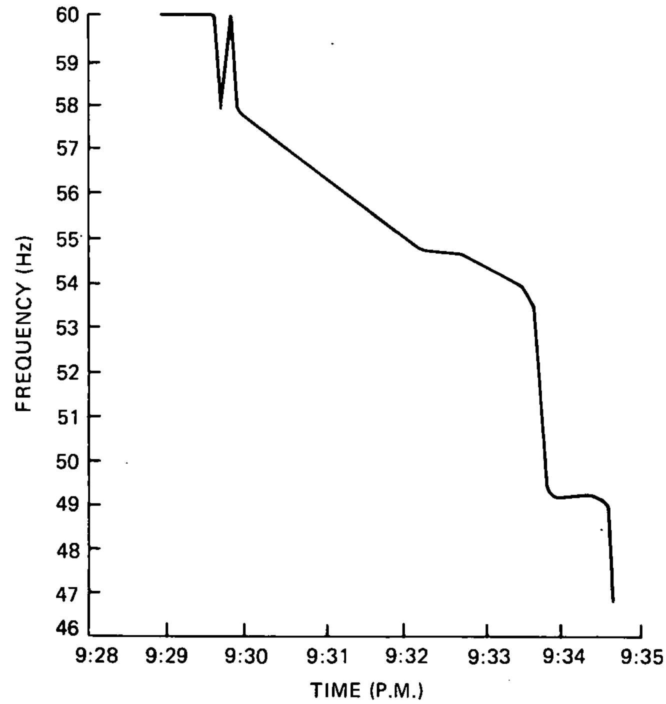
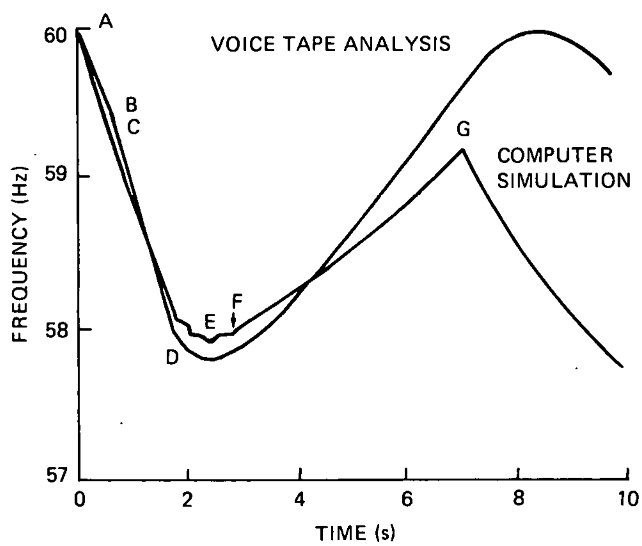


Figure V-23.—System frequency vs. time, determined from energy control center audio tape recorder.

showed that the frequency declined over the first 2 seconds at a rate between 1.0 and 1.3 Hz/second with an abrupt change at 2 seconds as a result of load



A: LINDEN TO GOETHALS 230-kV LINE TRIPPED AT TIME T = 0+ s
B: PLEASANT VALLEY TO MOHANSIC 138-kV LINE TRIPPED AT T = 0.57 s
C: PLEASANT VALLEY TO CARMEL 138-kV LINE TRIPPED AT T = 0.75 s
D: 4-kV LOAD SHED AT 59.3 Hz
E: 4-kV AND LOW-VOLTAGE NETWORK LOAD SHED AT 58.8 Hz
F: NETWORK LOAD SHED AT 58.3 Hz
G: RAVENSWOOD NO. 3 TRIPPED

Figure V-24.—System simulation of July 13, 1977, disturbance: 345-kV bus frequency vs. time.

shedding. The absolute frequency at this point ranged between 57.4 and 57.9 Hz. At least three levels of underfrequency relays operated to shed load. These were set to operate at 59.3, 58.8, and 58.3 Hz. An additional, fourth and final block of load shedding, set to operate at 57.8 Hz, was assumed to operate at the 2-second point in the FERC staff simulation. This block was shed at a later time in the Con Edison computer simulation. An audit of underfrequency relay targets indicated that a total load of 2,230.6 MW, or 37.3 percent, was shed automatically by underfrequency relays. The total amount covered by the first three underfrequency settings was about 1,435 MW, or 24.0 percent. After the initial drop, the frequency recovered at a rate of between 0.25 and 0.80 Hz/second for 4 to 6 seconds. At a point in this period, the Ravenswood No. 3 generating unit carrying 844 MW of load tripped off by loss of field relay. Loss of this unit left the island area with a net generation deficiency between 8.3 and 21.6 percent, depending upon whether the fourth block of load shedding was activated before or after tripping of Ravenswood No. 3. The frequency declined again at a rate of between 0.4 and 0.5 Hz/second. The results of the Con Edison analysis and the FERC staff simulation with regard to frequency after islanding are shown in figures V-24 and V-25, respectively. Table V-8 gives the

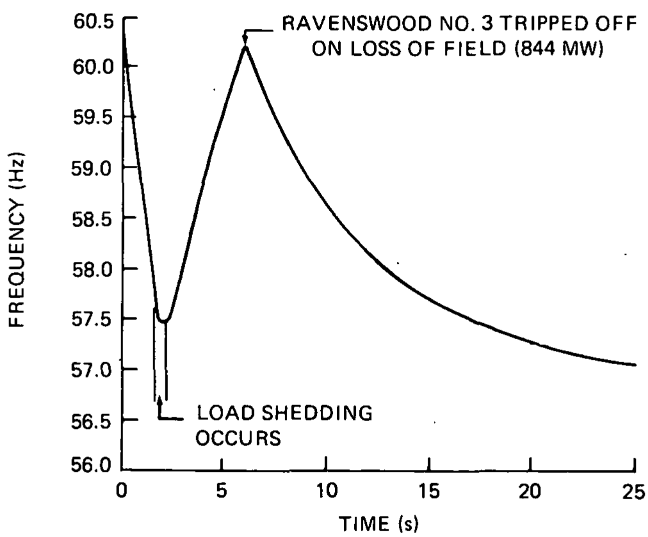


Figure V-25.—FERC staff analysis of estimated frequency response beginning 9:29:41 p.m., July 13, 1977: frequency vs. time.

Table V-8.—*Automatic Load-Shedding Schedule*

Frequency (Hz)	Average commit time (cycles)	Relay time delay (cycles)	Load shed (MW)
59.3	34	32	268.7
58.8	34	32	255.9
58.8	34	10	383.0
58.3	38	9	527.0
57.8	29	9	796.0

load-shedding schedule used in the FERC simulation.

For the FERC simulation the following characteristics were used:

Characteristic	*Value*
System load	5,981 MW
System generation	4,282 MW
Spinning reserve	0
System H	4.6
System D	1.5

System H, or inertia constant, is a measure of the energy stored in system generator rotors, related to the size of the generators. Numerically it is equal to the stored energy in megajoules at the rated speed divided by the total generator rating in megavolt-amperes. System D is a measure of the change in system load as a function of system frequency expressed as the proportional change in load, in percent, for a 1-percent change in frequency.

The conclusion concerning the automatic underfrequency load shedding is that it operated correctly to arrest the initial frequency decline and that the frequency apparently would have returned to normal except for voltage complications on the system that tripped additional generating capacity.

As a result of the automatic load shedding, a large amount of inductive reactive load was disconnected. This left the system with a surplus of reactive supply, generated mainly by the large capacitive reactance of the extensive 138-kV and 345-kV underground cable transmission system. Consequently, the system voltage rapidly increased to excessive levels. A voltage rise to about 11.5 percent above normal operating voltage at some locations at about 3 seconds into the isolated period is indicated. Automatic voltage regulators on the generating unit responded to reduce excitation to lower the voltage. Indications are that the voltage was moderating and was in the process of being returned to acceptable levels when the Ravenswood No. 3 generating unit began to absorb excessive amounts of reactive power. The automatic voltage regulator on the Ravenswood No. 3 generating unit drastically reduced excitation to overcome this effect. In the process, the voltage-current relationship appeared to the unit's loss-of-field relay as a loss of excitation, and the relay tripped the unit.

Immediately after the loss of Ravenswood No. 3, the frequency of the isolated Con Edison system dropped from 60.0 to about 57.8 Hz. Then the remaining generation on the system was sufficient to maintain the system load at a frequency of 57.8 Hz. All underfrequency load shedding had already activated. No further load reduction could occur automatically, other than that obtained as the frequency declined further in proportion to the system characteristic of about 1.5 percent per 0.1 Hz.

During the next $3\frac{1}{2}$ minutes, the output from the remaining 19 steam-turbine generators and 14 combustion-turbine generators deteriorated gradually as the auxiliary equipment, such as feed-water pumps, induced draft fans, and fuel pumps slowed down because of the low system frequency. The effect was exacerbated, because the reduction in auxiliary performance reduced plant output, which reduced system frequency, which further reduced plant output, in a chain of effects. The rate of frequency decline during this $3\frac{1}{2}$-minute interval was linear, at about 1.0 Hz/minute.

When the frequency declined to about 54.0 Hz, Arthur Kill unit No. 3 tripped while loaded at about 450 MW. This caused a rapid drop in frequency to about 49.2 Hz. The system stabilized at this level for about 30 seconds; then all remaining generation units tripped in rapid succession as various auxiliary equipment failed to function at this exceptionally low frequency.

All units shut down safely with no incidents of wiped bearings or warped shafts. The Northeast Power Coordinating Council (NPCC) procedures permit their member systems to take steps to protect generating equipment if the frequency drops to 57.5 Hz for 10 seconds or 56.0 Hz for 0.35 seconds. The Con Edison powerplant operators maintained plant output longer than required by the NPCC policy.

Chapter VI

RESTORATION SEQUENCE AND EQUIPMENT DAMAGE ASSESSMENT

RESTORATION SEQUENCE

Introduction

This chapter contains a detailed description of the restoration of service in Con Edison's service area after the shutdown of the system at about 9:36 p.m., July 13, 1977. Also included is a brief description of equipment damage that occurred during restoration. Conclusions and recommendations are given along with the sequence narrative.

A diagram of the Con Edison transmission system is inserted inside the back cover for reference in following the restoration sequence.

System Status Before Restoration

By the time of complete system shutdown, transmission ties between the Con Edison system and adjacent systems were completely severed. The 345-kV transmission ties to Pleasant Valley in the north (80 and W81) were open at Pleasant Valley, and the 345-kV tie to Ladentown in the northwest (Y88) was deenergized at Ladentown. The 345-kV tie to Ramapo (Y94), also in the northwestern area of the Con Edison system, was energized to Con Edison's Buchanan North bus, but open breakers at Buchanan isolated this tie from the system. The 138-kV ties to Millwood East in the north (circuits 9825 and 9826) were open at Pleasant Valley, and the Jamaica-138 kV tie to the Long Island Lighting Co. (LILCO) in the east was open at Valley Stream. The 230-kV tie from Goethals to Linden Station in the Public Service Electric & Gas Co. (PSE&G) system was damaged during the disturbance and was unavailable for the restoration. The 345-kV interconnection with PSE&G at Farragut had been out of service since September 4, 1976, because of a failure in the phase angle regulator and was also unavailable for the restoration. Several other transmission line breakers on the 345- and 138-kV transmission system internal to the Con Edison system were in the open position. All 60-Hz generators were shut down, resulting in a complete loss of power to the 60-Hz and d.c. systems. Unit No. 13 at the 59th Street generating station was running, but isolated from the main system.

Plan for Restoration

Immediately following the shutdown, rapid system restoration without full sectionalizing was attempted in an effort to reenergize portions of Westchester and isolated parts of the city that were connected together at this time. The attempt was abandoned after successive transmission line trips and the report of a fire at Buchanan Substation.

At approximately 10:45 p.m., a meeting of top-level operations management personnel was held to review the system status and to develop a plan for restoration of the system. The meeting included the assistant vice president of operations; the manager of operations; the chief, assistant chief, and duty system operator; and the chief district operator. The following plan for the restoration, having six parts, was developed:

(1) Isolation of the 345-kV system and establishment of an express tie from adjacent utilities in the north through Westchester to Staten Island for connection with the Arthur Kill plant

(2) Extension of the 138-kV transmission system from Pleasant Valley to Buchanan via Millwood

(3) Use of the 138-kV feeder from LILCO for picking up load and establishing express feeders for synchronizing the Astoria generators

(4) Use of available gas turbines at Gowanus and Narrows for supplying some Brooklyn load after a synchronizing feeder was established and, if required, having these units available for start-up of the Ravenswood plant

(5) Isolation of parts of the 138-kV system and putting Arthur Kill No. 2 on line

(6) Isolation of tie feeders and reestablishment of the 25-Hz system

The implementation and coordination of part 1 of the plan were assigned to the chief system operator. Parts 2 to 5 were assigned to the manager of the system operations department and the assistant chief system operator. Part 6 of the plan was assigned to a system operator with particularly extensive knowledge of the 25-Hz system. The assistant vice president of operations was in overall charge.

Detailed Sequence of the Restoration Effort

Immediately following shutdown, an attempt was made to restore the system rapidly, without extensive sectionalizing of the transmission network. Simultaneous closing of circuits 80 and W81 into the energized 345-kV bus at Pleasant Valley Substation was unsuccessful, as was an attempt to close into Sprain Brook and Eastview Substations from Ramapo Substation via circuits Y94 from Ramapo to Buchanan North and W93/W79 from Buchanan North to Eastview and Sprain Brook. A third effort involved closing circuit W97 to Buchanan South Substation and thus to line Y88, connecting to an energized bus at Ladentown Substation. Circuit 901L&M to LILCO was also closed unsuccessfully during this time.

The attempt at rapid restoration consumed slightly more than 1 hour and was terminated shortly after the report of a fire at Buchanan Substation. At this point, the six-part plan discussed previously was initiated, and by midnight some progress had been made with the first three parts—the 345-kV express feeder, the 138-kV development in the north, and the extension of the 138-kV Long Island tie. The 345-kV transmission had been successfully extended from Ladentown to Millwood and from Millwood south to Eastview and Sprain Brook. Also, the 138-kV transmission was restored from the 115-kV bus at Pleasant Valley, and the 138-kV/345-kV transformer was restored at Pleasant Valley. Transmission feeders were also established from Pleasant Valley south to the 138-kV buses at Carmel and Mohansic, and from LILCO to the 138-kV buses at Jamaica and Corona in Queens. Problems had already been encountered in the use of the gas turbines at the Narrows and Gowanus generating stations under part 4 of the plan. Preparatory activity for development of Arthur Kill generation had been initiated under part 5, and the restoration of the transmission ties in the 25-Hz system was underway. Most feeder and load-serving breakers had been opened at the 345-kV substations, and selective 138-kV breaker operations had been initiated to isolate the load from the 138-kV transmission buses in preparation for further moves on the 138-kV system. The effects of high voltages had already been experienced during the rapid restoration; as early as 11:16 p.m., reports of less oil pressure than normal for cable insulating oil were being recorded.

By 1:50 a.m., July 14, a second 345-kV tie had been established in the north and the 345-kV transmission had been extended south to Dunwoodie Substation and to the 138-kV stations at Dunwoodie North and South. The Westchester 138-kV network had been extended south to the 138-kV bus at Millwood East and through Millwood West to breakers at Buchanan that were open.

The 138-kV tie from Long Island had been successfully extended through Astoria and North Queens to Hell Gate, 179th Street, and Sherman Creek in the Bronx as early as 1:16 a.m. At 1:26 a.m., feeder potheads on circuits 15053 and 15054 at 179th Street failed because of low insulating oil pressure, and the transmission in the Bronx was again deenergized. By 1:01 a.m., Arthur Kill No. 3 boilers were lit off, and the unit was rolled in preparation for bringing it on line.

Low oil pressure on circuit M51 from Dunwoodie to East 13th Street Substations in the heart of Manhattan and on the circuit from East 13th Street to Farragut Substations in Brooklyn had forced a revision in the plan for development of the 345-kV network. The revised plan required resectionalizing for development of circuit W71 from Dunwoodie to Rainey Substations and of circuit 62 from Rainey to Farragut Substations. At 1:50 a.m., energization of a voltage compensation reactor on circuit Y50 at Dunwoodie ruptured the pothead on Y50.

Problems in establishing black-start gas turbines at Ravenswood, Hudson Avenue, Narrows, and Gowanus generating stations delayed restoration of light and power facilities at Farragut and Rainey Substations, thereby compounding or extending problems of restoring adequate insulating oil pressure.

At 2 a.m., circuit 71 was energized from Dunwoodie to Rainey, and at 2:06 a.m., the pothead on 71 failed at Dunwoodie, tripping the circuit and postponing further extension of the 345-kV transmission to the south.

By 1:53 a.m., Arthur Kill No. 3 unit was available for service, and efforts were made to establish a synchronizing source for the Arthur Kill generation by establishing an express tie to Jamaica. An unenergized 345-kV tie was established between an open breaker at the Arthur Kill generating station and Farragut Substation. With transformation at Farragut, a 138-kV link between the 345-kV bus at Farragut and the 138-kV bus at Jamaica was established through Hudson Avenue to an open breaker at Jamaica.

At 3:25 a.m., the No. 2 generating unit at Astoria was placed in service and synchronized with the Queens transmission network. Between 2:00 and 3:45 a.m. additional load was picked up in the Queens area and major segments of load were picked up in the Westchester area.

At 3:45 a.m., the open breaker at Jamaica was closed, and the Long Island tie tripped, deenergizing the entire Queens area, resulting in second loss of load and tripping the only steam unit synchronized at this time. The loss of load resulted in high voltage, causing a lightning arrester on circuit 778 at Hudson Avenue to rupture and fires to start in the Hudson Avenue plant.

During the period between midnight and 3 a.m., repeated unsuccessful efforts to establish gas-turbine generation at the Narrows and Gowanus plants and the availability of Arthur Kill generation at 1:53 a.m. led to abandoning part 4 of the plan at 3 a.m. and merging part 4 with parts 3 and 5. Damage at the Narrows

Station and difficulties experienced with the barge generation at Gowanus contributed to this decision.

By 4 a.m., the 25-Hz transmission ties were almost totally restored. Few difficulties were encountered in restructuring the tie feeders, but some problems were experienced with gas turbines, and an attempt to place a steam unit on line was unsuccessful when the unit tripped at 2:30 a.m. because of low load. At 3:50 a.m. a small amount of power was provided to the transit authority to supply light and signal power.

By 4:15 a.m., the second 138-kV feeder between the Millwood and the Buchanan Substations had been reestablished and the station light and power at Indian Point No. 3 Station had been returned to normal.

By 2:30 a.m., a portable diesel generator was on the way to Rainey Substation, and by 3 a.m., an emergency diesel was in the 13th Street Substation to restore oil pressure on the oil-filled cables. Station light and power were restored at Rainey by 4 a.m., and at Sprain Brook from Dunwoodie by 3:48 a.m. By 4:15 a.m., oil pumps had been started on feeders at Sprain Brook, but at 4:31 a.m., station light and power at Rainey were interrupted. By 5 a.m., the Rainey 345-kV bus had been sectionalized to accommodate energization of feeder 72 from Sprain Brook and extension of the 345-kV network to the south was renewed at 6:19 a.m. when feeder 72 was energized to Rainey. At 6:25 a.m., an emergency portable diesel generator was in Farragut and the station was being sectionalized to energize feeders between Rainey and East 13th Street. By 9:10 a.m., 345 kV was reestablished at Rainey, Farragut, and East 13th Street and 138-kV at Queensbridge, Vernon, Sherman Creek, and East 179th Street.

Between 3:45 and 6:25 a.m., the Queens transmission had been reenergized up to Astoria, North Queens, and Jamaica, and the Queens load was picked up a second time. Arthur Kill generation had been used successfully to energize Staten Island load, and transmission ties between Fresh Kills and Greenwood had been established but not synchronized with other areas of the system. At 6:25 a.m., when Fresh Kills transmission was tied to Gowanus feeder 42232 at Greenwood, the Staten Island transmission and Arthur Kill No. 3 tripped, interrupting service to the restored Staten Island load.

By 12:45 p.m., Arthur Kill No. 2 was on line, Staten Island load was picked up again, and the Staten Island 138-kV transmission system was made continuous with Vernon and Rainey feeders. The 345-kV network was extended beyond Farragut to Fresh Kills. The objective of part 1 of the plan had been reached, and additional 345-kV ties to the north were established by closing feeders 80 and W81 at Pleasant Valley and Millwood. Additional 345-kV ties were also developed from Millwood through East 13th Street to Farragut and between Farragut and Rainey. The 345-kV transmission system was almost completely restored.

The Queens 138-kV transmission had been successfully extended to Hudson Avenue East, but Astoria No. 2 was tripped again as a result of a pothead failure on a station light and power feeder at Astoria, and the Flushing network load was tripped at Corona to relieve overloads on circuit 901 to Valley Stream.

With 345-kV at East 13th Street and Farragut, the 60-Hz supply to frequency changers at Kent Avenue and 74th Street was energized, and generation was brought up at the 74th Street Station, enabling the pickup of some traction load.

By 5:53 p.m., the 138-kV ties between Queens and Farragut were completed, and the remaining available 345-kV feeders had been energized. In-city generation had been placed on line at Astoria and Ravenswood but tripped for various reasons. Arthur Kill generation was on line and the 345- and 138-kV transmission systems were totally restored. Load was being picked up systematically through the service area. A major step in the restoration of the Bronx load took place at 3:15 p.m., when the Sprain Brook/Tremont 345-kV tie was energized. Within the next hour, most of the Tremont/East 179th Street 138-kV transmission ties were restored, and at 4:44 p.m., these ties were made continuous with the 345-kV Sprain Brook/Tremont tie. At 5:47 p.m., Parkchester Substation, supplied via Tremont and East 179th Street, picked up customers in northern Bronx. Other major developments within the 3 to 6 p.m. time frame were the tripping of Ravenswood No. 2 at 4:36 p.m. (the unit had been restored at 3:05 p.m.), the energizing of the last major 345-kV line, and the synchronizing and tripping of Astoria No. 4 at 5:18 and 5:53 p.m., respectively.

By 6 p.m., July 14, the system was well on its way to complete restoration. Several 138-kV ties between Astoria West, Hell Gate, and Bruckner were restored, and by 7:13 p.m., customers in the central Bronx network were being picked up from Bruckner Substation. Southern Bronx customers were picked up from Parkchester at 6:30 p.m., and the remaining Manhattan and Brooklyn customers were being picked up gradually. The major events after that time to complete restoration were the synchronization of Indian Point No. 3 to Buchanan Substation at 7:07 p.m., the synchronization of Astoria No. 4 at 7:21 p.m., the return of Ravenswood No. 2 at 7:38 p.m., and the synchronization of Astoria No. 2 at 8:38 p.m.

A more complete restoration chronology is given in appendix J.

Description of Load Pickup

The restoration of customer service generally followed restoration of the transmission networks, reflecting the need first to provide a power source and then to balance load pickup with available generation to maintain generator stability and transmission loading. Load pickup was also an integral factor in efforts to control voltage as the transmission network was reconstructed.

The availability of synchronizing power at interconnection points in the north and on Long Island led to the first customer restoration in these areas, with Queens and Westchester load being restored as the synchronizing source was extended through the transmission network in these areas. Jamaica load in Queens was picked up as early as 1:47 a.m., July 14, and in the Westchester area as early as 1:59 a.m. Early progress in these areas enabled restoration of major transmission ties in the Bronx and northern Manhattan, but equipment damage at East 179th Street frustrated these efforts and resulted in some delay in the ultimate restoration of customers in the Bronx. Development of Arthur Kill generation enabled pickup in the Richmond area as early as 4:09 a.m., but both the Richmond area and the Queens developments suffered secondary losses of restored customers as a result of difficulty in the transmission restoration. From about 10 a.m., July 14, when the 345-kV transmission network had been reestablished in the Farragut/East 13th Street area, distribution load pickup proceeded smoothly through the remainder of the restoration effort. At approximately 6:30 p.m., loads served from the Brownsville Substation were interrupted for a second time to degas cable feeders, but these loads were restored again at approximately 8:30 p.m.

A detailed presentation of the load pickup during the restoration is given in table VI-1.

Table VI-1.—*Area Restoration; Customer and Load Pickup*

Time	Station or substation	Customers: Number	Customers: Portion of total (percent)	Customers: Cumulative portion (percent)	Maximum hour independent loads: Load (MW)	Maximum hour independent loads: Portion of total (percent)	Maximum hour independent loads: Cumulative portion (percent)
a.m.:							
1:47	Jamaica	74,000	2.72	2.72	147.0	1.69	1.69
1:59	Pleasantville	105	.00	2.72	.3	.00	1.70
2:27	Millwood West	2,380	.09	2.81	58.2	.67	2.37
3:00	Elmsford No. 2	1,540	.06	2.87	−7.8	.00	2.46
3:42	Mohansic Radial	2,250	.08	2.95	12.0	.14	2.59
3:43	Buchanan	2,895	.11	3.06	6.0	.08	2.67
3:45	Jamaica	−74,000	−2.72	.34	49.3	.57	3.24
	Harrison	225	.01	.35	1.1	.01	3.25
	White Plains	9,420	.35	.69	−147.0	−1.69	1.56
3:50	Granite Hill	7,670	.28	.97	25.6	.29	1.85
	Dunwoodie	1,245	.05	1.02	19.8	.23	2.08
4:09	Wainwright	18,250	.67	1.69	37.8	.44	2.52
4:27	Elmsford No. 1	205	.01	1.70	1.0	.01	2.53
4:40	Washington Street	11,950	.44	2.14	34.3	.39	2.92
4:46	Fresh Kills	950	.03	2.17	2.7	.03	2.95
5:24	Jamaica	74,000	2.72	4.89	147.0	1.69	4.65
5:46	Willowbrook	15,600	.57	5.46	33.0	.38	5.02
6:25	Wainwright	−18,250	−.67	4.79	−37.8	−.38	4.65
	Willowbrook	−15,600	−.57	4.22	−33.0	−.44	4.21
	Fresh Kills	−950	−.03	4.19	−2.7	−.03	4.18
6:32	Jackson Heights Radial	2,000	.07	4.26	4.2	.05	4.23
	Jackson Heights	50,000	1.84	6.10	104.9	1.21	5.43
6:35	Elmsford No. 1 Radial	3,055	.11	6.21	14.3	.16	5.60
6:40	Pleasantville	18,340	.67	6.88	47.2	.54	6.14
6:45	Millwood West Radial	19,740	.73	7.61	51.9	.60	6.74
6:58	Jamaica Radial	76,000	2.79	10.40	151.0	1.74	8.48
7:39	Lenox Hill	35,000	1.29	11.69	151.8	1.75	10.23
9:03	Long Island City	101,000	3.71	15.40	285.0	3.28	13.51
9:15	Rego Park	62,000	2.28	17.68	173.4	2.00	15.50
9:16	Harlem	43,325	1.59	19.27	164.0	1.89	17.39
9:23	Central Park	30,350	1.12	20.39	121.8	1.40	18.79
9:35	Buchanan Radial	22,040	.81	21.20	49.6	.57	19.36
9:45	Willowbrook	15,600	.57	21.77	33.0	.44	19.80
	Wainwright	18,250	.67	22.44	37.8	.38	20.18
	Fresh Kills	950	.03	22.47	2.7	.03	20.21
9:49	Ocean Parkway	92,670	3.41	25.88	205.3	2.36	22.57
9:50	Flushing	48,000	1.76	27.64	138.0	1.59	[illegible]
	Harrison Radial	18,053	.66	28.31	91.5	1.05	[illegible]

Table VI-1.—*Area Restoration; Customer and Load Pickup*—Continued

Time	Station or substation	Customers: Number	Customers: Portion of total (percent)	Customers: Cumulative portion (percent)	Maximum hour independent loads: Load (MW)	Maximum hour independent loads: Portion of total (percent)	Maximum hour independent loads: Cumulative portion (percent)
9:57	Lincoln Square	16,540	.61	28.92	77.3	.89	26.11
9:58	Rockefeller Center	6,745	.25	29.16	83.9	.97	27.07
10:00	Sheepshead Bay	62,000	2.28	31.44	145.4	1.67	28.74
	Sheepshead Bay Radial	2,416	.09	31.53	5.7	.07	28.81
10:05	White Plains Radial	45,412	1.67	33.20	237.9	2.74	31.55
	Rego Park Radial	23,000	.85	34.04	64.4	.74	32.29
10:27	Elmsford No. 2 Radial	22,645	.83	34.88	114.7	1.32	33.61
10:33	Fox Hills Radial	32,950	1.21	36.09	106.2	1.22	34.83
	Fox Hills	3,200	.12	36.20	10.3	.12	34.95
10:35	Maspeth	58,000	2.13	38.34	128.1	1.47	36.43
10:59	Columbus Circle	24,710	.91	39.24	102.0	1.17	37.60
11:39	Flushing	−48,000	−1.76	37.48	−138.0	−1.59	36.01
11:40	Fresh Kills Radial	36,050	1.32	38.81	103.1	1.19	37.20
	Dunwoodie Radial	11,727	.43	39.24	186.7	2.15	39.35
11:42	Washington Street Radial	50,575	1.86	41.09	144.9	1.67	41.02
12:03	Washington Heights	28,860	1.06	42.16	105.7	1.22	42.23
p.m.:							
1:30	Granite Hill Radial	40,373	1.48	43.64	135.0	1.55	43.79
1:57	Pennsylvania	15,170	.56	44.20	137.8	1.59	45.37
2:25	Madison Square	34,570	1.27	45.47	188.9	2.17	47.55
2:40	Plaza	11,415	.42	45.89	130.4	1.50	49.05
2:58	Bay Ridge	70,000	2.57	48.46	140.5	1.62	50.67
3:00	Park Slope	86,500	3.18	51.64	158.8	1.83	52.49
3:15	Ridgewood	63,000	2.32	53.95	129.0	1.49	53.98
	Crown Heights	56,000	2.06	56.01	127.6	1.47	55.45
3:20	Richmond Hill	85,000	3.12	59.13	169.0	1.95	57.39
	Times Square	13,880	.51	59.64	116.4	1.34	58.73
3:35	Greeley Square	12,700	.47	60.11	115.2	1.33	60.06
3:43	Williamsburg	43,669	1.60	61.72	142.9	1.65	61.71
3:48	Borough Hall	94,500	3.47	65.19	180.2	2.07	63.78
3:50	Kips Bay	4,540	.17	65.36	37.7	.43	64.21
	Flushing	48,000	1.76	67.12	138.0	1.59	65.80
4:18	Flatbush	73,200	2.69	69.81	144.9	1.67	67.47
4:25	Riverdale	42,000	1.54	71.35	60.6	.70	68.17
	Sherman Creek Radial	9,400	.35	71.70	13.6	.16	68.32
4:42	Fordham	97,900	3.60	75.30	157.0	1.81	70.13
5:01	Hudson Ave. Radial	0	.00	75.30	.0	.00	70.13
5:25	Grand Central	24,130	.89	76.18	180.8	2.08	72.21
5:47	Northeast Bronx Radial	40,800	1.50	77.68	52.4	.60	72.82
	Northeast Bronx	40,800	1.50	79.18	52.5	.60	73.42
6:24	Richmond Hill	−85,000	−3.12	76.06	−169.0	−1.95	71.48
6:25	Crown Heights	−56,000	−2.06	74.00	−127.6	−1.47	70.01
6:26	Ridgewood	−63,000	−2.32	71.69	−129.0	−1.49	68.52
6:30	Southeast Bronx	40,900	1.50	73.19	76.1	.88	69.40
6:34	City Hall	14,980	.55	73.74	78.2	.90	70.30
6:36	Chelsea	19,715	.72	74.46	153.8	1.77	72.07
6:48	Southeast Bronx Radial	31,300	1.15	75.61	58.2	.67	72.74
6:57	Murray Hill	6,160	.23	75.84	42.0	.48	73.22
7:13	Central Bronx	48,900	1.80	77.64	.6	.01	73.23
	Bruckner Radial	400	.01	77.65	76.4	.88	74.11
7:15	Herald Square	9,470	.35	78.00	110.0	1.27	75.37
7:20	Cooper Square	33,200	1.22	79.22	161.4	1.86	77.23
7:35	Trade Center	1	.00	79.22	57.0	.66	77.89
	Cortland	7,850	.29	79.51	89.8	1.03	78.92
8:02	Turtle Bay	7,400	.27	79.78	87.3	1.00	79.93
8:06	Beekman	22,400	.82	80.60	92.1	1.06	80.99
8:11	Sutton	27,500	1.01	81.62	115.3	1.33	82.31
8:21	Hunter	22,050	.81	82.43	97.8	1.13	83.44

Table VI-1.—*Area Restoration; Customer and Load Pickup*—Concluded

Time	Station or substation	Customers: Number	Customers: Portion of total (percent)	Customers: Cumulative portion (percent)	Maximum hour independent loads: Load (MW)	Maximum hour independent loads: Portion of total (percent)	Maximum hour independent loads: Cumulative portion (percent)
8:29	Crown Heights	56,000	2.06	84.48	127.6	1.47	84.91
8:30	Ridgewood	63,000	2.32	86.80	129.0	1.49	86.39
8:32	Richmond Hill	85,000	3.12	89.92	169.0	1.95	88.34
8:34	Corona No. 1 Radial	45,500	1.67	91.59	130.8	1.51	89.85
8:40	Fulton	5,840	.21	91.81	91.9	1.06	90.90
9:03	Flatbush Radial	31,982	1.18	92.98	63.30	.73	91.63
9:15	Brownsville No. 2 Radial	26,178	.96	93.95	52.0	.60	92.23
9:45	Glendale Radial	9,500	.35	94.30	21.0	.24	92.47
10:06	West Bronx	68,000	2.50	96.79	109.4	1.26	93.73
10:12	Bowling Green	10,180	.37	97.17	135.9	1.56	95.30
10:21	Greenwich	8,350	.31	97.48	40.5	.47	95.76
10:25	Sheridan Square	13,360	.49	97.97	100.2	1.15	96.92
10:35	Canal	10,700	.39	98.36	92.1	1.06	97.98
10:39	Yorkville	44,620	1.64	100.00	175.8	2.02	100.00
Total		2,721,131	100.00	–	8,786.7	100.00	–

Analysis and Evaluation of the Restoration Effort

The following discussion first addresses the Con Edison plan for restoration of the system and then considers the actual implementation of that plan. In the latter, the factors considered include manpower availability, knowledge, and activity; communication needs and capabilities; the existence of guides or procedures; coordination of all resources (manpower, communication facilities, procedures, and equipment); personnel conformance with established guides or procedures; equipment performance; elements of system design; and unforeseen occurrences.

Six-Part Restoration Plan

In evaluation of the plan of restoration one of the first items to be considered is the propriety of the attempt at rapid restoration. Con Edison's established operating procedures for restoration of the system from complete shutdown contain nothing that suggests such an effort should be made. In addition, during the period of the rapid-restoration attempt and after, field operators called in information about breaker and disconnect status, checked for and isolated any damaged facilities discovered, and noted ground switch and relay operation. Under such conditions, the picture of actual system status available to the system operator was less than complete. With the small probability of success inherent in such an attempt, the less-than-complete picture of system status, and the potential for equipment damage, the attempt may have been ill advised. On the other hand, had the attempt proved successful, the benefits could have been significant. Therefore, a review of the concept of rapid restoration should be made, and depending on the findings of a detailed analysis, operating specifications should be modified either to preclude a rapid-restoration attempt or to provide guides and appropriate training for enhancing the probability of success.

The six-part plan initiated after the attempt at rapid restoration contained three major segments, which, in total, addressed all evident avenues of approach to restoration of the system. The immediately available power sources for synchronizing included adjacent systems to the north and LILCO to the east. Use of these sources was important to the plan, in parts 1 and 3. The southwestern tie between Goethals and Linden of the Public Service Electric & Gas Company of New Jersey (PSE&G) was damaged in the shutdown and was not available for synchronizing power in the southwest. The only remaining possibility for establishing a source of power for restoration was the development of in-city generation, and this development was addressed in parts 3 to 5 of the plan.

Part 2 of the six-part plan addressed restoration of the Indian Point plant in the northwestern portion of the system. Return of Indian Point No. 3 would allow the displacement of some imported restoration power from interconnections to the north.

Part 6 of the six-part plan was directed toward restoration of the 25-Hz and d.c. systems. Because normal operating specifications for these two systems are combined and separate from those for restoration of the 60-Hz system, it is reasonable for the 25-Hz and d.c. systems to be a separate part of the six-part plan.

The simultaneous but independent development of the restoration plan, parts 1 to 6, was feasible and possessed the possibility for reasonably expeditio system restoration. The plan was also generally consi tent with established operating procedures for bla start of generators having such capability. Comments regarding responsibility assignments to various personnel are included in the evaluation of the manpower and coordination aspects of the restoration.

Manpower Availability and Preparation

Interrogation of Con Edison personnel in the field and at the energy control center and members of the Con Edison investigating task force indicates manpower availability did not represent a problem during the restoration. Field personnel on watch during the disturbance remained on duty and were reinforced by early arrival of personnel scheduled for following shifts; additional personnel called in by watch supervisors arrived promptly. The situation at the energy control center was similar, with the overall availability of personnel more than adequate for meeting requirements of the restoration. The few instances where restoration activity was curtailed because of unavailable field personnel were confined to the very early period of restoration and had minimal effect on the overall restoration effort.

The personnel selected for management and coordination of the restoration were top-level representatives of Con Edison operations department, each with extensive training and experience in system operation. These included the assistant vice president of the operations department; manager of the operations department; the chief system operator, assistant chief system operator, and a system operator with particularly significant experience regarding the 25-Hz system. Coordination of switching operations was assigned to chief district operator. It appears that the personnel selected for direction of the restoration encompassed the most experienced and best trained operating personnel available to the company. It also appears that the other personnel involved in the restoration effort were well trained and well informed regarding their responsibilities.

Communications Facilities

The Con Edison communication facilities include radio communication facilities, radio-telephone lines (RTLs), direct telephone lines (leased), and commercial telephone. The facilities are described in detail in appendix K. Early in the restoration effort, lack of emergency power prevented full use of the facilities; heavy reliance was placed on commercial telephone service.

The UHF and VHF systems were totally inoperative after complete shutdown of the Con Edison system and were not available again until approximately 12:05 a.m., July 14. One of the emergency power supplies for the main repeater station was inoperative before the disturbance and the second failed to start. When attempts were made to use the backup repeater station, the emergency power supply to it also failed to operate. In the period from 9:35 a.m., July 13, to 12:05 a.m., July 14, Con Edison personnel managed to transfer emergency supply for the backup repeater station from its normal emergency gasoline unit to the Irving Place emergency diesel. This transfer has since been made permanent because the diesel was felt to be more reliable than the gasoline unit.

The main repeater station was out of service for approximately 13½ hours, but with the backup station in service, UHF communications were restored to a satisfactory state by 12:05 a.m., July 14.

Overall, the communication capabilities available to Con Edison before the disturbance appeared to be adequate from the standpoint of facilities in place. The possibility of a triple-contingency loss of emergency power supply to the UHF repeater stations was extremely remote, but its occurrence did uncover shortcomings in the emergency operation of RTLs and direct telephone lines. This deficiency has since been corrected. Even with the problems encountered, communications in the early hours, though less than perfect, were maintained via commercial telephone lines held open by operators at both ends and via operative RTLs and direct telephone lines. Some of the problems encountered in the earlier phases of the restoration were partially due to reduced communication capabilities in some areas. In general, however, the communication problems were not considered major by personnel at the energy control center.

Operating Procedures for Restoration

Con Edison had, before the July 13, 1977, power failure, extensive procedures for restoration of the system, covering such topics as the following:

(1) Isolation and sectionalizing
(2) Black start of certain generators
(3) Start-up procedures for the 60-Hz, 25-Hz, and d.c. systems
(4) Reestablishment of transmission ties
(5) Load pickup to balance generation

During the actual restoration on July 13 and 14, 1977, while procedures were generally followed, there were a number of instances in which they were found to be out of date, not in sufficient detail, and lacking in clarity.

Operation Problems During Restoration

During the rapid-restoration period, operators in the energy control center observed unusual voltage conditions; shortly after the rapid-restoration attempt it became evident that inadequate insulating oil pressures were being recorded on the 345- and 138-kV transmission-cable systems. After initiation of the six-part plan it also became evident that black-start gas-turbine and other generating facilities were not performing in accordance with system design expectations. Under these conditions and pressed by the urgency of the situation, the operators began to implement the six-part plan as rapidly as possible. The following sections examine the problems of low insulating oil pressures, unusual voltage conditions, and the station light and power supply problems. In addition, an attempt is made to evaluate the difficulties in starting generating facilities, the overall coordination of the six-part plan, the conformance of field personnel with established operating procedures, and other aspects of the restoration effort.

Cable Oil Pressure Problems

The transmission system south of Dunwoodie in Westchester consists primarily of underground cable with only a few short runs of overhead line and numerous submarine river crossings. Most, if not all, of the underground cable used in the Con Edison system is oil-filled pipe-type cable with several key transmission facilities using forced cooling. The normally cooled pipe-type cable generally has three phase conductors located in a pipe that is filled with oil and kept under pressure. Each conductor is insulated with oil-impregnated paper and covered by metallic and tape shielding. The power-handling capabilities of such lines are limited by the ability of the feeders to dissipate the heat generated by power flow over the length of the feeder. The heat from normally cooled cable is dissipated to the surrounding earth, and the power-handling capability is therefore affected by soil conditions, ambient temperatures, and the proximity of other heat sources. In forced cooling, a coolant is circulated through the cable or in a separate channel close to the cable, thereby increasing the heat dissipation and power-carrying capability.

The pipe-type cables are generally terminated in oil-filled porcelain bushings called potheads through which the cable circuits are connected to substation buses. The insulating oil generally fills the cables from the pothead base at one terminal to the pothead base at the other terminal.

Pumps used to maintain oil pressure on the cables in the Con Edison system normally operate from a.c. sources provided by the station light and power supply, which is fed from system generators and transmission networks. Total shutdown of the Con Edison system completely interrupted the power supply to these pumps, and at the time, no emergency power supply was available to replace the normal supply. As a result, shortly after the attempts at rapid restoration of the system, low insulating oil pressure readings were being reported by field operators. The absence of emergency pumping power supply has been attributed to the company's belief that oil pressures in the cables would persist long enough, even under total shutdown conditions, to allow restoration of station light and power supply before cable pressures were inadequate. However, pressures considerably below normal were eviden' early in the restoration effort.

The problem of low oil pressure had a significant effect on the company's ability to restore the system, in that low insulating oil pressure on several feeders led to flashovers in potheads, or cable failures and loss of the feeders involved. Restoration of the 345-kV express feeders in the first part of the restoration plan was delayed dramatically. Inadequate pressure on cable circuit M51, between Sprain Brook and 13th Street, forced the abandonment of the plan to energize 13th Street via M51 and required resectionalization of the stations to accommodate the alternate plan of reenergizing Farragut Substation via cable feeder 71 from Sprain Brook to Rainey and 62 from Rainey to Farragut. After this delay, efforts to energize feeder Y50 led to a ruptured pothead and a tripped feeder. Feeder 71 was then energized, and shortly after, tripped because of a pothead failure. Following the tripping of circuit 71, further extension of the 345-kV line was postponed until adequate insulating oil pressure could be established on the underground cable system.

The need for emergency diesels at the stations was an outgrowth of difficulties in establishing station light and power supply via black-start generating facilities at Hudson Avenue, Ravenswood, Narrow, and Gowanus generating stations. The damage to gas-turbine transformer No. 2 at Hudson Avenue, during the rapid-restoration effort, and a later lightning arrester failure on feeder 32079 stymied efforts to establish station light and power at Farragut and East 13th Street via Hudson Avenue, the usual source. Under such circumstances, established operating procedures require the transfer of an emergency diesel to Farragut and 13th Street.

Problems at Ravenswood generating station delayed restoration of the usual emergency station light and power source for Vernon and Rainey, and the problems at Narrows and Gowanus prevented restoration at these stations via Greenwood Substation. Following transfer of the diesels, station light and power were restored at Rainey at 4 a.m., July 14, and extension of the 345-kV line was resumed at 6:19 a.m., when feeder 72 was energized between Sprain Brook and Rainey Substations.

Failure to establish station light and power sources from the black-start generation extended the period of low insulation oil pressure operation on the 345-kV system and magnified the impact of not having independent emergency supplies for the oil pumping stations. Con Edison has since installed emergency power supplies for substation auxiliary power at 18 locations throughout the system.

The low pressure problems also resulted in loss of th North Manhattan and South Bronx 138-kV transmission ties at 12:23 a.m., when the potheads of feeders 15053 and 15054 at 179th Street ruptured because of low insulating oil pressures after the transmission ties had been restored. The damage also caused considerable delay in restoring loads in these areas.

Failures of transformers Nos. 3 and 6 at Farragut coupled with the pothead failures on circuits 38B01 and 38B02 between Farragut and Brownsville also made it necessary to shut down the Brownsville Substation manually to degas the potheads on other feeders to Brownsville. Table VI-2 lists 345-kV transmission lines for which restoration was delayed because of low oil pressure. These postponements delayed the overall restoration effort approximately 5 hours.

System Voltage Control Problems

Voltage planning for the Con Edison transmission system defines the maximum allowable voltage to be 1.05 times nominal, or 362 kV on the 345-kV system and 145 kV on the 138-kV system. Operating procedures require the immediate reduction of voltages in excess of these values. They also contain instructions for voltage regulation during peak-load and light-load conditions and for control of high voltage during black start of the system. The latter instruction is dated 1968 and is therefore out of date, but most of the general guidelines are currently applicable.

Control of voltage at various points in a transmission network is a fundamental problem in electric power engineering. It is more difficult in systems where underground cables are used extensively because of the relatively high distributed parallel capacitance of such cables. In such systems, including the Con Edison system, series reactors are used to compensate for the parallel capacitive reactance.[1]

Despite awareness of the potential problems associated with high voltage and an evident effort to provide means to deal with it, there were extended periods of high voltage during the system restoration. Actions taken by the energy control center to control voltage during restoration included all that were identified in the operating guides, involving source voltage reduction, reactive switching, tap changing and load pickup, and others that were not identified, such as reactive power circulation. Despite these efforts, high voltage contributed to, or caused, considerable damage to facilities during the restoration period.

Data for evaluation of the voltage control problems are less than complete. During normal operations voltage data from a multitude of locations throughout the Con Edison system are telemetered to both the energy control centers periodically, and information is readily available for almost every significant point on the system at the New York Power Pool (NYPP) control center. In addition, one four-channel and one six-channel strip chart at the energy control center plot voltage versus time for ten locations on the 345-kV system, and a three-channel chart plots similar data for three locations on the 138-kV system. Finally, oscillograph readings are available for certain locations throughout the system.

Information is available from the NYPP on a 6-second-scan computer printout for those periods and locations for which telemetering is in operation. Computer voltage data logging in Con Edison's energy control center is available to the system operators but is not readily available in a printout form. With the loss of station service, telemetering is not available and voltage data are lost.

Strip chart readings are similarly affected in that the interruption of station service also interrupts the recording of voltage data. Tables VI-3 and VI-4 show preliminary voltage data made available by the company. A review of the tables clearly shows a lack of information for the early hours of the restoration. These early hours encompass the rapid-restoration period, wherein extensive voltage-related damage was experienced. Strip chart readings available for Farragut Substation show high voltages that range from a low of 367 kV to a high of 381 kV over a period of 1 hour; for half of this time, voltage exceeded 375 kV. Strip chart plots also show voltage excursions at various times throughout the day with voltages sustained for extended periods of time (in excess of 30 minutes) between 380 and 392 kV. The 138-kV strip charts go off scale, indicating 150 kV or more, for extended periods.

The black-start voltage control program for the Con Edison system considers the availability of reactive compensation and its appropriate switching. It is also based on prescribed reactive power absorption capabilities of peripheral power sources and on the defined reactive power absorption capability of baseload units

Table VI-2.–*Feeders for Which Restoration Was Delayed Because of Oil Pressure Problems*[1]

Feeder	Connecting stations	
	From	To
72	Dunwoodie	Rainey
M51	Sprain Brook	East 13th Street
M52	Sprain Brook	East 13th Street
X28	Sprain Brook	Parkchester
45	East 13th Street	Farragut
46	East 13th Street	Farragut
B47	East 13th Street	Farragut
48	East 13th Street	Farragut

[1] Based on preliminary data submitted by Con Edison.

[1]For a technical discussion of this topic, see, for example, W. D. Stevenson, Jr., *Elements of Power System Analysis*, McGraw-Hill, 1962.

Table VI-3.—*Preliminary Voltage Data From 345-kV Stations*

Time	Voltage (kV)							
	Power pool data					Strip chart data		
	Millwood West	Dunwoodie	Rainey	Goethals	Farragut	Farragut	Sprain Brook	Fresh Kills
p.m.:								
8:00	352.9	351.5	351.6	351.8	346.8	354	349	353
8:30	352.2	350.5	350.8	351.1	346.4	353	347	353
9:00	330.8	330.2	357.2	338.8	333.7	328	333	336
9:30[1]	381.2	378.6	383.4	377.1	375.8	362	358	362
a.m.:								
3:09[2]	–	–	–	–	–	379	–	–
3:19	–	–	–	–	–	381	–	–
3:29	–	–	–	–	–	376	–	–
3:39	–	–	–	–	–	376	–	349
4:09	–	–	–	–	–	367	–	380
4:39	–	–	–	–	–	362	–	373
5:09	–	–	–	–	–	358	–	368
5:39	354.7	356.5	346.1	300.4	346.5	355	–	365
6:09	354.7	356.5	346.1	300.4	346.5	352	–	360
6:39	356.6	356.2	346.1	300.2	346.5	357	353	364
7:09	367.0	366.4	372.3	300.7	346.5	366	374	373
7:39	363.1	362.2	366.1	300.7	346.5	363	353	372
8:09	355.6	355.0	352.0	300.6	346.5	356	351	358
8:39	361.8	360.2	362.1	300.6	346.5	362	263	366
9:09	376.0	374.8	382.7	300.6	346.5	382	–	392
9:39	362.8	362.5	368.5	300.6	346.5	353	–	365
10:09	341.7	341.9	338.2	300.5	346.5	343	–	–
10:39	336.2	336.5	333.9	300.5	346.5	337	–	–
11:09	343.2	343.2	342.6	–	346.5	343	342	342
11:39	347.4	347.2	349.0	300.4	346.5	343	350	345
p.m.:								
12:09	349.5	351.2	352.3	300.4	351.4	350	353	348
12:39	347.6	348.9	352.4	300.4	350.2	349	351	347
1:09	355.9	354.6	360.1	300.5	356.9	356	358	350
1:40	353.0	357.8	365.1	300.4	361.4	357	363	352
2:10	356.6	357.7	364.0	359.4	360.2	360	362	351
2:40	357.4	355.3	362.0	358.2	358.6	359	360	350

[1] System separation at 9:29 p.m.
[2] System shutdown at 9:36 p.m.; no telemetering or strip chart data available until 3:09 a.m.

in the Con Edison system. The latter represents approximately two-thirds of the total reactive power absorption capability available to the system operator for black-start voltage control; none of it was available in the early hours of the July 13 restoration. In addition, inductive compensation on circuit Y50 was not available for voltage control because it was damaged.

In an effort to gather more information regarding these voltage problems, Con Edison has attempted to simulate system conditions by computer and to reproduce voltages recorded by oscillograph operation. These investigations indicate that the closing of single energized Westchester circuits into the remaining Con Edison system with limited sectionalizing, as in the rapid restoration, is similar to closing a relatively large inductive element (an overhead line) in series with a transmission network that is largely capacitive and, therefore, appears as a relatively large capacitor. The resultant series resonance effects are still under investigation but are believed to be at least partially responsible for the high-voltage conditions produced in the rapid-restoration period.

The lack of sectionalizing in the rapid-restoration effort resulted in repetitive energization of facilities under high-voltage conditions. Every time a circuit was closed in at Millwood West it also energized W93 on backfeed from Sprain Brook and energized Farragut via circuits between Sprain Brook, Rainey, and Farragut.

Voltage control difficulties experienced during the restoration indicate that a full review of black-start voltage control requirements is warranted. Also, in light of the poor availability of voltage data for analysis of the restoration, improved facilities for recording voltage data should be considered.

Table VI-4.—*Preliminary Voltage Data From 138-kV Stations*

Time	Voltage (kV)		
	Sherman Creek	Dunwoodie	Jamaica
p.m.:			
8:00	138	137	136
8:30	138	136	135.5
9:00	135	134.5	130.5
9:30	137	138.5	132.5
a.m.:			
1:40[1]			
2:00	–	137.5	–
2:30	–	137	–
3:00	–	137.5	–
3:30	–	137	–
4:30	138.5	138.5	–
5:00	139.5	140	–
5:30	140	137	–
6:00	–	137	–
9:30	–	129	142
10:00	135.5	127	136.5
10:30	136.5	123	135.5
11:00	141	123	135
11:30	140	122	136.5
p.m.:			
12:00	140	122.5	136.5
12:30	139	129	136
1:00	140.5	129.5	138
1:30	140	129	138.5
2:00	142	129	140.5
2:30	141	133.5	139
3:00	140	133	138.5
3:30	137.5	133	137
4:00	137	133.5	137
4:30	136.5	136.5	136.5
5:00	137	136.5	134.5
5:30	136.5	136	134
6:00	137	136.5	134
6:30	138	137	135.5
7:00	137.5	137	135.5
7:30	138	136.5	135
8:00	137.5	135.5	135
8:30	135.5	135.5	134.5

[1] No telemetering or strip chart data available after 9:30 p.m. and before 2:00 a.m.

Difficulties in Starting Generation

Table VI-5 shows a unit-by-unit chronological summary of black-start generating difficulties experienced by Con Edison during the service restoration of July 13 and 14. During this period, there were 94 instances of unit trippings or delays in startup. With few exceptions the units were returned to service within 24 hours.

Table VI-6 is a condensed version of table VI-5, with generating difficulties grouped under four major headings. There were 27 instances of difficulties associated with steam plant generation. Of these, 11 (41 percent) were related to auxiliary equipment and auxiliary power supply facilities, 6 (22 percent) were problems caused by network feeders, 5 (18½ percent) were difficulties associated with turbines and boilers, and the remaining 5 were due to miscellaneous causes such as fires and control problems. There were 67 trippings and delays during startups of gas turbines. Of these, 30 (45 percent) were caused by the failure of the units themselves, 16 (24 percent) were network related, such as overloading and reverse power flow, 11 (16 percent) were related to auxiliary equipment and associated power supply facilities, and 10 (15 percent) were due to miscellaneous causes.

Problems resulting from the failure of auxiliary equipment and their power supply facilities can to some extent be attributed to the state of the electrical system external to the equipment. Auxiliary equipment performs a variety of electrical and mechanical tasks, such as lubricating moving parts, circulating oil, pumping cooling water, pumping boiler feedwater, and other functions required in support of the main steam- and power-generating equipment. Auxiliary equipment is usually driven by electric motors whose source of power during normal operating condition is from unit station service transformers. Therefore, the systemwide electrical disturbances during the decline and rapid-restoration period could have an adverse effect on this equipment.

Table VI-5.—*Generating Difficulties Encountered During Restoration, July 13 and 14, 1977*

Trip time	Station	Type[1]	Unit number	Comments[1]
p.m.:				
9:35	Astoria	Steam	5	Unit tripped automatically. Initial efforts to restore this unit were canceled because of fires in air preheaters. Unit was synchronized July 17, 1977.
	74th Street	Steam	–	At 9:41 p.m. frequency changers 1 and 2 were taken out of service because there was no auxiliary power for cooling.
	Narrows	GT	–	At 1:47 a.m. the system operator notified the site that feeder 23161 for barge No. 1 would not be available. At 2:00 a.m. system operator ordered barge No. 1 at baseload. The units were delayed because of vibration caused by the removal of ratcheting to conserve battery power.
10:13	Narrows	GT	2-1	Unit tripped automatically because of overload.
			2-2	Breaker closure attempted twice. Both attempts failed because of overload.

Table VI-5.—*Generating Difficulties Encountered During Restoration, July 13 and 14, 1977*—Continued

Trip time	Station	Type[1]	Unit number	Comments[1]
10:14	Narrows	GT	2-2	Breaker tripped automatically because of overload.
10:16	Narrows	GT	2-2	Breaker tripped automatically because of overload.
10:30	Ravenswood	GT	1	Unit attempted for black start and failed to start because of water in diesel fuel, low air pressure (nitrogen bottle hooked up to operate gas valves and air-operated equipment), low-charge cadmium batteries (exhaust-gas temperature trip controller had to be jumped out), pressure regulator for lubricating-oil system failed to function, and cooling water blew out of oil cooler vent cap.
	Hudson Avenue	GT	–	Fire broke out on GT 2 at 10:30 p.m. 138-kV lightning arrester on phase A of transformer No. 2 disintegrated. This transformer connects GT 3, 4, and 5 to Farragut Substation. Heavy rain extinguished fire before firemen arrived. GT 1 would not start because of low air pressure and low battery voltage. Nitrogen bottles were used to build up air pressure in the GT air-storage tank, and jumpers were installed between GT 4 batteries and GT 1. This unit was brought up to full speed but was not connected to the 27-kV bus by district operator order. District operator was preparing to make station live from transmission system. At 9:46 a.m. (July 14, 1977) switching was completed.
10:32	Bowline Point	Steam	1	Unit tripped automatically.
10:45	Ravenswood	GT	1	Gas header vent valve opened automatically because of loss of control air. Gasoline-powered air compressor was used to close header vent valve.
11:30	Astoria	GT	4-1	Unit tripped because of overexcitation caused by charging current on feeder.
11:31	74th Street	GT	2	Unit tripped while attempting to connect to bus because of high lubricating-oil temperature.
11:55	Astoria	GT	4-1	Unit tripped automatically. It failed to synchronize.
	Indian Point	Steam	3	Instrumentation and control problems with black-start diesel generator. GT 1 availability delayed.
a.m.:				
12:05	Astoria	GT	4-1	Unit tripped automatically. It failed to synchronize.
12:15	Astoria	GT	4-1	Unit tripped automatically. It failed to synchronize.
	74th Street	GT	2	Unit failed to start because of low battery voltage.
12:47	59th Street	GT	2	Unit tripped via reverse power flow.
1:22	Astoria	GT	4-1	Unit tripped automatically because of transformer overexcitation relay. Low bus voltage was observed.
			4-2	Unit tripped automatically because of transformer overexcitation relay. Low bus voltage was observed.
1:30	Narrows	GT	[2]2	138-kV feeder 23162 was isolated because of smoking insulator and lightning arrester.
1:37	Narrows	GT	2-2	Unit tripped automatically because of reactive power overload.
1:41	Narrows	GT	2-3	Unit tripped automatically because of reactive power overload.
1:45	Narrows	GT	2-1	Unit tripped because of lightning arrester flashover on barge No. 2 transformer.
1:50	59th Street	GT	1	Unit tripped because of reverse power.
1:51	Waterside	GT	1	Unit tripped automatically because of 48-V battery lead burning. In further restart attempts, idle set solenoid and associated relay failed. Low battery voltage prevented further restart attempt. A temporary emergency feed was run from diesel to unit to recharge batteries.
2:16	Gowanus	GT	1-4	Unit tripped automatically because of overload.
2:35	59th Street	GT	1	Unit tripped because of reverse power flow.
2:38	Hudson Avenue	GT	1	Unit failed to start because of low air pressure and low battery voltage. Nitrogen bottles were used to build up air pressure in storage tank. Jumpers were installed between the unit and d.c. controls.
2:43	59th Street	Steam	115	Unit tripped because of insufficient load. It was kept out of service because of insufficient 25-Hz electrical demand.
3:00	74th Street	GT	2	Unit failed to start because of lubricating-oil pump failure.
3:45	Astoria	Steam	2	Network disturbance.
3:46	Astoria	Steam	3	Unit tripped because of loss of auxiliary power. Unit was restored at half capacity because of feeder problem until 2:15 p.m.
			4	Unit tripped because of network disturbance.
4:25	74th Street	GT	2	Unit tripped while starting No. 9 boiler feed pump.
	Gowanus	GT	1-4	Feeder problem.
4:31	Ravenswood	GT	3-3	Unit tripped because of loss of auxiliary power.
			3-4	Unit tripped because of loss of auxiliary power.
	74th Street	Steam	–	Ignition problems on boilers 121 and 122.

Table VI-5.—*Generating Difficulties Encountered During Restoration, July 13 and 14, 1977*—Continued

Trip time	Station	Type[1]	Unit number	Comments[1]
5:18	Astoria	GT	4-2	Unit tripped automatically because of loss of field.
5:30	Ravenswood	GT	9	Unit tripped because of control problems.
6:22	Astoria	GT	1	Unit tripped because of governor control problem. Lost instrumentation on unit 3 and auxiliary on unit 5.
6:23	Astoria	GT	1	Unit restarted. However, it would not synchronize manually or automatically.
6:25	Arthur Kill	Steam	3	Unit tripped because of low electrohydraulic control pressure. Alternate pump was found not running.
			2	Unit lost flame because of unit 3 trip, which caused the loss of power to fuel pump.
	Astoria	Steam	5	Fire in duct at 7:42 a.m. No. 54 air heater on fire at 7:43 a.m.
7:46	74th Street	Steam	11	Unit tripped manually because of frequency problems on 25-Hz system. At 8:45 a.m. frequency changer No. 2 started on 25-Hz cycle side; unable to synchronize because of high-frequency on 25-Hz system. At 9:00 a.m. frequency changer No. 1 started on 60-Hz side; unable to synchronize because of high frequency on 25-Hz side.
	Astoria	GT	1	Unit would not synchronize manually or automatically.
	74th Street	Steam		Boilers 121 and 122 were taken out of service. There was no fuel for diesel driving air compressor.
9:45	Gowanus	GT	2-3	Generator breakers tripped automatically because of reactive power overload.
			2-8	Generator breakers tripped automatically because of reactive power overload.
			4-3	Generator breakers tripped automatically because of reactive power overload.
9:49	59th Street	Steam	13	Boilers 114 and 115 tripped via overcurrent relay.
	Indian Point	Steam	3	At 9:55 a.m. six rupture disks ruptured on low-pressure turbine.
10:15	Ravenswood	Steam	2	Boiler tripped because of low voltage.
10:44	Astoria	GT	8	Unit tripped automatically because of high bearing temperature.
	Gowanus	GT	–	At 10:45 a.m. barge Nos. 2 and 4 generator breakers opened manually because of reactive power overload. At 11:30 a.m. barge Nos. 2 and 4 were shut down to restore backfeed on 138-kV feeders.
11:37	Astoria	Steam	2	Unit tripped automatically because of 13-kV phase B pothead rupture on station light and power feeder.
	Arthur Kill	Steam	3	Boiler feed pump problem were developed at 12:14 p.m. while the unit was rolling.
p.m.:				
12:16	Gowanus	GT	2-7	Unit tripped automatically because of turbine problem.
12:19	Astoria	GT	1	Unit tripped because of loss of field.
12:28	Narrows	GT	1-7	Unit tripped because of overload.
12:29	Gowanus	GT	2-3	Unit tripped because of reverse power.
12:35	Astoria	GT	7	Unit tripped because of low compressor suction.
1:15	Astoria	GT	4-3	Startup was delayed because of defective gas trip. Unit tripped automatically because of high engine vibration.
2:25	Ravenswood	Steam	2	Unit tripped while locking fields.
2:50	Ravenswood	GT	3-4	Unit tripped because of vibration.
3:30	Ravenswood	GT	5	Unit tripped because of turbine failure.
			6	Unit tripped because of control problems.
3:32	Astoria	GT	2-1	Unit tripped because of high transformer temperature.
3:43	59th Street	Steam		Boiler No. 115 tripped.
	East River	Steam	6	At 3:45 p.m. while filling No. 60 boiler, no indication of electrical feed to air preheater was noticed. Condition was being checked by electrical maintenance.
3:54	59th Street	Steam	13	Unit tripped because of ruptured blowdown line.
3:55	59th Street	Steam	13	Boiler 111 tripped because of tripping of east boiler feed pump.
4:20	Astoria	GT	3-1	Gas trips holding unit off line.
			3-2	Gas trips holding unit off line.
	Indian Point	Steam	3	Reactor critical at 4:33 p.m.
4:36	Ravenswood	Steam	2	Unit tripped because of trouble with induced-draft and forced-draft fan control system.
	74th Street	Steam	–	Ignition problem with boiler 120.
5:01	Astoria[3]	GT	3-3	Unit tripped by faulty gas detector in unit 3-1.
			3-4	Unit tripped by faulty gas detector in unit 3-1.
			4-1	Unit tripped because of units 3-3 and 3-4 tripping, which caused loss of auxiliary air compressor.
			4-2	Unit tripped because of units 3-3 and 3-4 tripping, which caused loss of auxiliary air compressor.

Table VI-5.—*Generating Difficulties Encountered During Restoration, July 13 and 14, 1977*—Concluded

Trip time	Station	Type[1]	Unit number	Comments[1]
			4-3	Unit tripped because of units 3-3 and 3-4 tripping, which caused loss of auxiliary air compressor.
5:02	Astoria	GT	3-1	Gas leak found in broken starter on unit 3-1.
			3-4	
			3-3	
			3-1	
	74th Street	Steam	–	Boiler No. 120 lit off.
	Waterside	Steam	–	Frequency changer No. 1 was delayed because of switching problem at 5:28 p.m.
5:31	59th Street	GT	1	Unit tripped because of high exhaust temperature.
	Ravenswood	GT	3-1	Firing of this unit was delayed because of a series of control problems in the sequencer and fuel control.
5:45	Ravenswood	GT	3-2	–
5:53	Astoria	Steam	4	Differential had low fuel oil. Manually operating valve failed to close.
6:25	59th Street	GT	1	Unit tripped because of high exhaust temperature.
6:55	59th Street	GT	1	Unit tripped because of high exhaust temperature.
7:20	Ravenswood	GT	3-4	Unit tripped because of low lubricating oil.
8:01	59th Street	GT	2	Unit tripped because of tripping of auxiliary power breaker.
8:10	Astoria	GT	12	Unit tripped because of loss of d.c. voltage and subsequent loss of common computer.
			13	Unit tripped because of loss of d.c. voltage and subsequent loss of common computer.
8:13	East River	Steam	6	Unit tripped because of motor generator set problem. There were several delays in lighting this unit because of problems with electrical switching and air compressor system.
8:25	Ravenswood	GT	8	Unit tripped because of problem with lubricating-oil pressure.
9:20	59th Street	GT	1	Unit tripped because of high exhaust temperature.
10:12	Narrows	GT	2-1	Unit tripped because of overload.
10:27	East River	Steam	6	Unit tripped because of low vacuum. Both circulators tripped out, burners pull out. Various problems with auxiliary equipment delayed the startup on units 5, 6 and 7.
	Ravenswood	Steam	1	After shutdown of boiler No. 10 a water wall tube ruptured. This unit was returned to service at 9:31 p.m. July 16, 1977.
			3	After the shutdown of this unit at 9:30 p.m. one of 12 rupture disks on the low-pressure turbine exhaust hood failed. Further problem caused by the leak in the breaker delayed the return of this unit to service until 6:36 p.m. of July 15, 1977. North boiler held out because of feed water leaks.

[1] GT = gas turbine. [2] Barge 2. [3] Unit 2-2 firing was delayed because of shorted annunciator panel.

Table VI-6.—*Major Causes of Equipment Failures During Restoration Period*

Plant type	Number of interruptions: Network	Auxiliary equipment and facilities	Generator, turbine, or boiler	Miscellaneous
Steam	6	11	5	5
Gas turbine	16	11	30	10

Problems associated with gas turbines were of mechanical and thermodynamic natures. Although some of these failures are expected during system disturbances, the majority of these failures could be prevented if a systematic program of inspection, maintenance, and periodic testing and evaluation of their operating conditions were implemented.

Coordination and Conformance With Established Procedures

Review of activities that took place over the course of the restoration indicates that coordination was generally effective and that operations in the field were reasonably efficient. With the problems encountered with oil pressure, voltages, and black-start generation, restoration went fairly well, despite dramatic setbacks that have been attributed to equipment misoperation or breakdown.

Some events did take place that indicate either inappropriate operator actions or lack of adequate coordination of field activity by the control center, and others raised questions regarding judgment. Operation of the gas turbines at the Narrows generating station at 10:12 p.m. through 10:16 p.m. shows a possible breakdown in coordination. Gas turbine units 2-1 and 2-2 were successively placed on line at this time and tripped out automatically; unit 2-2 was closed in twice

Because this was in the period of rapid restoration, there may have been some attempt to coordinate this activity with the closure of lines in the north, but the net result was unsatisfactory. These units were placed on line before station operators had any chance to complete procedures for isolating and restarting the system. Transmission paths between the Narrows generation and numerous load feeders at Farragut and other stations were still intact when the units tripped out on overload. At approximately 11:30 p.m. gas turbine unit 4-1 was brought on line at Astoria, believed to be connected to an isolated feeder (34129), but the unit tripped on transformer overexcitation as a result of energizing feeders 34129 and 34182 at the same time. The unit was again placed on line at 11:35 p.m., 12:05 a.m., and 12:15 a.m., and it tripped automatically each time. Earlier, during the rapid restoration, circuit 901 was closed in between LILCO and Con Edison at Jamaica. The line tripped immediately, and little information is available to explain why the line was energized at that time. Its capacity is far less than that of the 345-kV lines in the north and the chance of its remaining in service was remote, because little sectionalizing had been accomplished before its closure.

Despite major system problems with voltage and oil pressure, once major sectionalizing began, development of the 345-kV system proceeded smoothly until the need to change direction became evident. Following pressure checks on Y50 and 71, the attempt to energize Y50 to place a reactor in operation led to a ruptured pothead. Investigation of this incident indicates Y50 was damaged before the attempt to energize the feeder. The feeder connection to the reactor and the Dunwoodie bus is a temporary arrangement, pending completion of circuit Y50, which will ultimately be tied to the LILCO system. Within this temporary arrangement, the oil supply to feeders Y50 and 71 is common. Because the failure of the Y50 pothead created a leak in the oil supply for 71, the decision to energize feeder 71 almost immediately after the damage to Y50 reflects poor judgment or lack of awareness on the part of the control center personnel. The ensuing damage to feeder 71 might have been avoided had more significance been attached to the previous damage on Y50.

During the rapid restoration, gas-turbine transformer No. 2 was damaged at Hudson Avenue. Three of the five gas turbines at Hudson Avenue are tied to the Farragut bus through this transformer and an allocated transmission feeder. Of the remaining two gas turbines at Hudson Avenue, No. 2 was out for maintenance, and No. 1 was ready for service at 10:53 p.m., but it was not called for by the system operator until 2:30 a.m. When the unit was ordered on line, it failed to start. As of 4:15 a.m., station operators noted they were still working on the unit, and the unit was finally rolled at 8:35 a.m., and then it was not used.

Because Hudson Avenue is the normal supply for station service to Farragut and 13th Street Substations, the difficulties at Hudson Avenue should have had significantly more impact on the energy control center personnel than was evident during the disturbance, especially in connection with the oil pressure problems that became evident fairly early (11:16 p.m.) in the restoration. The fact that operating procedures for Farragut call for use of a portable generator to provide emergency power at Farragut if there were difficulties at Hudson Avenue should have encouraged restoring station service to Farragut and 13th Street as early as possible. This would have provided a.c. power to insulating oil pumps in these stations and could have reduced the delay associated with the low oil pressure condition. But the diesel generator was not sent to Farragut until 6:25 a.m., July 14.

At 9:45 a.m., transformer No. 3 at Farragut was destroyed by through-fault current due to a fault on feeder 38B01. This situation was a direct result of a breakdown in operating procedures. The 1968 general operating guides require removal of phase overcurrent relays as a prelude to energizing certain feeders to prevent switching surge tripping of the feeders. The 1976 operating procedure for Farragut specifically requires that all relays remain untouched. The through-fault current that destroyed transformer No. 3 was not interrupted, because relays at Farragut on feeder 38B01 had been removed from service. Because even the 1968 general guides caution against totally removing fault protection from a feeder, the incident warrants prompt attention in Con Edison's efforts to improve operating procedures.

Interruptions of Restored Load Areas

Over the period of the restoration effort there were several occasions in which system operations or equipment failure led to the interruption of areas previously restored. Following are brief descriptions of five major occurrences of this nature:

(1) As early as 1:16 a.m., July 14, the closure of breaker 4W at Astoria East energized 138-kV feeders from Astoria through Hell Gate, 179th Street, and Sherman Creek to the Dunwoodie 138-kV South and North Substations. At 1:26 a.m., the failure of potheads at 179th Street on feeders 15053 and 15054, between Hell Gate and 179th Street, caused the circuits to trip. At the same time several feeders at Astoria East, two feeders and two transformers at Corona, and all of the Hell Gate/179th Street/Sherman Creek transmission ties also tripped.

(2) At 3:45 a.m., closing of breaker No. 5 at Jamaica resulted in the interruption of circuit 901L&M from LILCO's Valley Stream Substation and loss of the entire Queens area, including the Jamaica network customers and generating unit No. 2 at Astoria. The closing of breaker No. 5 at Jamaica was intended to be the final step in tying the Arthur Kill area to the

synchronizing source available in Queens. Before 3:45 a.m., an unenergized transmission tie, including 345-kV circuits W26/W42 from Fresh Kills to Farragut; transformers 8, 9, and 10 at Farragut; 138-kV circuits 32077, 32078, and 32711 from Farragut to Hudson Avenue; and circuit 701 from Hudson Avenue to Jamaica were isolated from the system to provide a transmission tie between the open No. 5 breaker at Jamaica and the open No. 26 breaker at Fresh Kills. When breaker No. 5 at Jamaica was closed, breaker No. 1 on the 901L&M line opened at Jamaica (901L&M remained alive from Valley Stream). Load on the Astoria No. 2 unit went from 15 to 100 MW, frequency and voltage dropped at the station, and the unit tripped. The lightning arresters on B and C phases of circuit 778 in the east yard at Hudson Avenue ruptured, and fires started in the station. Instead of gaining a synchronizing tie at Arthur Kill the entire Queens restoration was interrupted, and equipment was damaged.

(3) Between 3:05 a.m. and 6:25 a.m., the 138-kV transmission ties between Fresh Kills and Greenwood were restored, and the Arthur Kill No. 3 unit was used to supply load at Fresh Kills, Willowbrook, and Wainwright Substations. At 6:25 a.m., breakers 1N and 2N at Greenwood Substation were closed. This tied Fresh Kills 138-kV feeder 29292 to Gowanus feeder 42232, which was energized to an open breaker No. 14 at Gowanus; to Narrows feeder 27162, which was isolated by open disconnects; and to transformer No. 5 at Greenwood. With this breaker closure, Arthur Kill generator No. 3 tripped and the Fresh Kills/Greenwood transmission ties, including the load picked up at Fresh Kills, Wainwright, and Willowbrook, were deenergized. The generating unit tripped because of low electrohydraulic control pressure. Based on preliminary investigations to date, a grounding switch on the phase angle regulator for circuit 42232 to Gowanus appears to have operated inappropriately at 6:25 a.m. when breakers 1N and 2N were closed at Greenwood. The inadvertent operation of the grounding switch should have tripped the circuit at Greenwood, or possibly even at Fresh Kills, and should not have tripped the unit.

(4) At 9:50 a.m., the Flushing network was picked up from Corona Substation, and at 11:35 a.m., Astoria generating unit No. 2 tripped, overloading LILCO feeder 901L&M between Valley Stream and Jamaica. The Flushing network was manually tripped in Corona at 11:38 a.m. to relieve the overload. The network was picked up again at approximately 3:50 p.m.

(5) Following restoration of Brownsville Substation, Crown Heights, Ridgewood, and Richmond Hill customers were picked up in Brooklyn at 3:15 p.m. Because of cable failures on Brownsville feeders 38B01 and 38B02 and the failures of Farragut transformers No. 3 and No. 6, which supply Brownsville feeders, combustible gas was found present in the cable oil supply. To prevent further damage to the remaining Brownsville feeders, it was necessary to deenergize Brownsville Substation to degas the remaining Brownsville feeders. The Crown Heights, Ridgewood, and Richmond Hill loads were interrupted with the Brownsville shutdown. The Richmond Hill network was restored again at 8:23 p.m., and the Crown Heights and Ridgewood networks were picked up at 8:30 p.m.

Delayed Restoration of the 25-Hz and d.c. Systems

The Con Edison 25-Hz system load is supplied from five generating stations with frequency changers (East River, East 74th Street, Kent Avenue, Waterside, and West 59th Street), and from two other substations: Hell Gate, through a frequency changer, and John Street, which is tied to frequency changers at the Hudson Avenue and Kent Avenue generating plants. These stations supply the 25-Hz power of the New York Central, Pennsylvania, New York-New Haven, and Long Island Railroads, the plant load of the New York City Transit Authority, the d.c. network load in mid-Manhattan, and a number of other customers.

Following complete shutdown, unit No. 13 at the 59th Street Generating Station was still in operation but isolated from the system. All other generators on the 25-Hz system were completely shut down. Unit No. 13 was ordered on line by the energy control center at 12:10 a.m., and by 12:12 a.m., was on line and feeding the energy control center.

By 4 a.m., transmission tie lines throughout the 25-Hz system had been restored with the exception of John Street feeders. The reconnection of the transmission system progressed with little difficulty except for some tripping of gas turbine facilities at 74th Street, 59th Street, and Waterside generating stations. Steam generating unit No. 15 was placed on line at 2:30 a.m., and at 2:43 a.m., tripped because of insufficient load on the unit. At 7:35 a.m., unit No. 11 at Waterside was brought on line, but at 7:46 a.m., the energy control center requested its removal because of high frequency on the 25-Hz system. The 60-Hz supply from Rainey was made available to East 75th Street at about 6:40 a.m., and at 8:10 a.m., the system operator at the energy control center requested the frequency changers at 74th Street, linking the 25-Hz and 60-Hz systems through East 75th Street, to be placed in service. At 8:45 a.m., operators at the 74th Street Station indicated that the frequency changers had been started on the 25-Hz side but that high frequency on the 25-Hz system prevented synchronization with the 60-Hz system. This occurred a second time when an attempt was made to synchronize 74th Street frequency changer No. 1 at 9 a.m. After these unsuccessful attempts, the operation of unit 13 at 59th Street was modified to lower frequency on the 25-Hz system. The 74th Street frequency changers Nos. 1 and 2 were brought on line at 9:33 and 9:37 a.m., respectively.

Kent Avenue frequency changers were ordered on line at 8:20 a.m., but at that time the 60-Hz voltage was too high. Voltage levels were acceptable by 9:30 a.m., and the frequency changer was delivering 5 MW to the 60-Hz system at 10:55 a.m.

Additional frequency changers were connected as load requirements dictated, and Waterside No. 2 frequency changer was ordered on line by the system operator at 4:30 p.m. The frequency changer at Hudson Avenue followed at 6:20 p.m., and the one at East River followed by 9:02 p.m. The Hell Gate frequency changer was not back in service until 12:06 a.m., July 15.

Evaluation of Emergency Power Supply for Health and Public Safety Facilities

Coordination of health and public safety facilities in the city of New York was achieved through the Mayor's emergency control board, which normally handles disasters in this city. The police commissioner and the director of the New York City Office of Civil Preparedness convened the board in the early morning hours of July 14. Because the New York telephone system was operational, a tremendous volume of telephone inquiries from the public and media was directed at the city's emergency operating center, which had broadcast its number to the public. For the millions in darkness, portable radios provided the only other source of official instruction. Local newspapers and television studios located in the blackout area were unable to operate. In general, telephone communications were stretched to their utmost during the outage, causing busy signals and delays of official messages.

Many important services were maintained during the outage period with the help of emergency generators. All bridges and tunnels operated by the port authorities of New York and of New Jersey were operational because a majority of their needs were supplied by PSE&G and port authority emergency generators supplied the rest. Of the many hospitals and similar institutions throughout the Con Edison service area, most had emergency generators that maintained satisfactory emergency operations, but many required assistance. The police department provided emergency power for four hospitals having inoperative emergency equipment and provided maintenance or repair services to 13 other establishments, including hospitals and nursing homes. Con Edison also maintains a pool of 50 or more small portable diesel generators, and 18 of these were dispatched to various locations throughout the service area. These provided power for lifesaving equipment in all areas of the city.

Fire departments and station houses throughout the blacked-out area were functional. Alarms, radio, and other voice communications were effective because of emergency equipment.

La Guardia and Kennedy Airports were capable of continuing operations. Each had sufficient generators to maintain public safety and traffic control, but flights were suspended from 9:30 p.m., July 13, until 6 a.m., July 14. One reason for this was the failure of obstruction lighting on large buildings in the vicinity. Air traffic scheduled for the period was sparse, and only 32 flights were diverted to other airports.

Surface transit operated by the New York City Transit Authority was operational, although some problems occurred in securing fuel. It was necessary to send vehicles to New Jersey to secure fuel for some buses.

Rapid transit was completely disrupted, but because of alert and prompt action by transit authority personnel, the impact of the power disturbance on subway riders was minimized. Between 9:20 and 9:30 p.m. various transit authority power department instruments indicated a deterioration of power and several automatic substations were lost. In addition, motormen at various locations reported to the command center that they were observing flashing or dark signals. Because of these reports, and through use of the two-way radio system that spans the 230-mile subway circuit, all 213 operating trains were ordered to the nearest stations where they were told to remain. In the next few minutes all automatic substations shut down. As a result of this decisive action, only seven trains with fewer than 1,000 passengers were stranded between stations. All passengers were evacuated by 12:10 a.m., July 14, with no reported injuries.

The operation of the emergency power supply to health and public safety facilities showed a generally adequate installation of emergency equipment. The police and fire department equipment was functional throughout the extended power disturbance, related communications were maintained, and police department equipment and expertise were used to alleviate problems in other areas of operation. Telephone communications were strained but functioning, radio communication with the public was operational, and most hospitals and other such service institutions operated successfully on emergency power. Emergency equipment at local airports performed satisfactorily, and bus transit and port authority facilities were available throughout the restoration period. Transit authority personnel were alert and their actions commendable during the decline. They dispatched emergency pumps and compressors that helped to control flooding.

A number of hospitals and other institutions required replacement or supplemental emergency power supply. Others required repair or maintenance service before adequate emergency operations could be established. In light of the critical nature of these services, procedures for testing emergency power facilities should be reexamined and measures taken to assure adequate emergency operations at these locations in the future.

EQUIPMENT DAMAGE ASSESSMENT

Significant damage during the July 13 disturbance involved four types of major electric power system equipment including lightning arresters, potheads, transformers, and one phase angle regulator.

Table VI-7 lists chronologically the equipment damaged during the disturbance, the extent of damage, and the system condition causing the equipment failures. All of the damage, except for the Goethals phase angle regulator, was sustained during the restoration, with a large part of the overall damage being experienced during the rapid-restoration phase. All damage was to transmission facilities, with no damage reported in the distribution areas of the system. Damage to the Goethals phase angle regulator was sustained during the separation of the Linden/Goethals tie just before complete isolation of the Con Edison system. The regulator was, in fact, the only major piece of equipment specifically identified as being damaged during the system shutdown. The facilities installed since the 1965 blackout, to assure safe system shutdown of generating units, performed adequately, bringing generating units to a stop without damage.

In summary:

(1) The damage experienced in system separation and shutdown was minimal.

(2) The equipment installed since the 1965 blackout to facilitate safe shutdown of generating units performed as expected and was a major factor in the safe shutdown of units during the July disturbance.

(3) The damage experienced during restoration was concentrated in the transmission system with no damage to distribution generation facilities.

(4) Most of the transmission system damage could have been avoided.

Table VI-7.–*Equipment Damages During Con Edison System Disturbance, July 13 and 14, 1977*

Day	Time	Location	Type of facility and system designation	Cause of damage	Extent of damage
July 13	p.m.:				
	9:29	Geothals Station	Phase angle regulating transformer 1N	Flashover of phase C selector switch during overloaded operation before and after opening of the Jamaica Valley Stream 138-kV tie to Long Island Lighting Co.	Stationary and moving selection switch and reversing switch drive loads burned; back in operation July 19, 1977
	10:30	Hudson Avenue Station	Lightning arrester, phase A of transformer GT 2	Failure during period of sustained system overvoltage	Replacement required
			Combustion turbine transformer GT 2	Failure during period of system overvoltage	Replacement of two "high-side" bushings required
		Farragut Substation	Autotransformer No. 6	Internal fault after energization during rapid restoration, before isolation of load feeders at Farragut Substation	Transformer replacement required
	10:33	Buchanan Substation	Lightning arrester, phases B and C of transformer TA5	Failure as a result of system overvoltage during repeated attempts at rapid restoration	Replacement required
			Auto transformer TA5	Failure as a result of system overvoltage during repeated attempts at rapid restoration	Transformer replacement required
	10:43	Astoria East Station	Lightning arrester associated with 138-kV bus, section 2E	Failure during rapid restoration attempt; probable cause: extended overvoltage	Replacement required
July 14	a.m.:				
	12:05	Astoria West Station	Lightning arrester, phase A, bus section 9N	Failure after attempt to synchronize Astoria combustion turbine 4-1 to North bus	Replacement required
	1:26	East 179 Street Station	Potheads phases A and B of feeder 15054	Internal flashover of pothead due to inadequate oil pressure, causing pothead rupture	Shattered porcelain from ruptured potheads damaging 6 coupling capacitor potential

Table VI-7.–*Equipment Damages During Con Edison System Disturbance, July 13 and 14, 1977*–Concluded

Day	Time	Location	Type of facility and system designation	Cause of damage	Extent of damage
			and phase C of feeder 15053		devices and bushing on 138-kV circuit breaker 1E; replacement of damaged equipment required
	1:05	Narrows Station barge 2	Lightning arrester, phase C, feeder 23162	Possibly multiple attempts to synchronize Narrows combustion turbine–preceded damage occurrence	Replacement required
	1:50	Dunwoodie Station	Potheads, phases A, B, and C, feeder Y50	Inadequate oil pressure resulting in internal flashover during attempts to energize feeders	Potheads replacement required
	2:10	Dunwoodie Station	Pothead, phase B of feeder 71	Inadequate oil pressure resulting in internal flashover during attempts to energize feeder	Pothead replacement required
	2:13	Dunwoodie Station	SF6 bus structure, coupling capacitors, and pothead enclosure for feeder Y50	Failure of phase B pothead of feeder 71 resulting in cable oil filling indicated structures	All affected equipment requiring removing and returning to manufacturer for cleaning
	2:52	Corona Station	Lightning arrester, phase A, feeder 18002	Failure after attempts to energize Corona Substation, through phase angle regulating transformer 2, via feeder 18002 from Jamaica Substation	Replacement required
	3:45	Hudson Avenue Station	Lightning arrester, phases B and C of feeder 778	Failed through overvoltage after attempt to energize feeder 701 via Jamaica Substation	Replacement required
	9:05	Farragut Station	Lightning arrester, phase A, transformer 8	Failed through overvoltage after attempt to energize portions of west ring bus	Replacement required
	9:45	Gowanus Station	Lightning arrester, phase C, phase angle regulating transformer R14	Reason for failure undetermined, to date	Replacement required
		Greenwood Station	Lightning arrester, phases A, B, and C of BKR15	Reason for failure undetermined, to date	Replacement required
	11:37	Astoria Station No. 2	Pothead	Reason for failure undetermined, to date	Replacement required
p.m.:					
	4:55	Farragut Station	Pothead, phase C of feeder 38B01	Inadequate oil pressure resulted in internal flashover during attempt to energize feeder	Replacement required
			Autotransformer No. 3	Through fault current associated with pothead failure in feeder 38B01, failure of protective equipment to isolate cable fault before transformer damage	Transformer replacement required because of main winding failure

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Chapter VII

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, conclusions and recommendations derived from the detailed analyses of chapters V and VI are gathered into major categories. Some of the recommendations presented in this chapter are not stated in the earlier chapters, but result from consideration of broader functional areas of power system management that requires study to determine the extent of any inadequacy that may exist as well as the remedial actions that are indicated. Of the conclusions and recommendations presented in this chapter, those considered to have the greatest importance and urgency have been summarized in chapter I. Detailed analyses and background material supporting the conclusions have been placed in the technical appendixes, appendixes F to L, which are referenced throughout this chapter. A number of corrective actions taken by Con Edison following the July 13, 1977, failure are listed at the end of this chapter.

The staff analysis and resulting conclusions and recommendations relate primarily to the conditions that existed on July 13 and 14, 1977. Although some of these conditions have been modified by Con Edison as a result of its own investigations and earlier recommendations, the discussion covers the full set of corrective measures viewed as necessary to minimize the probability of recurrence of the July 13 and 14 power failure.

In brief, the staff concludes that the root cause of the Con Edison system collapse and slow restoration was a lack of management alertness, leading to inadequate preparation for emergencies and insufficient attention to the operations function and the critical role of the system operator.

The measures already taken and others proposed by Con Edison to improve operational readiness and control are generally consistent with the staff recommendations and should significantly reduce the probability of a recurrence.

The major categories of detailed recommendations are—

(1) Management responsibility
(2) Control center and communications
(3) Selection, training, and supervision of operators
(4) System operating practices
(5) Design, operation, and testing of protective systems
(6) Emergency planning and operations
(7) System planning
(8) Compliance with reliability recommendations

MANAGEMENT RESPONSIBILITY

Conclusions

The investigation of the July 13, 1977, power failure and slow restoration shows serious instances of system and staff inadequacy and a lack of preparation for an emergency. Con Edison's management must accept responsibility for a general lack of alertness to the possibility of a major service interruption. The city of New York, with its dense population and unique concentration of commercial activity, requires an especially reliable electric power supply. Emergency procedures must be planned to minimize the possibility of service interruptions and, if such an interruption occurs, to assure that restoration is accomplished expeditiously. Operating management must give constant attention to the possibility of bulk-power-supply failure and must make certain that all operating personnel are ready to deal with emergencies by promptly carrying out planned procedures. The events of July 13 and 14 indicate that management had not exercised the degree of diligence necessary to assure that these requirements would be fulfilled.

The FERC staff's investigation revealed a number of examples of lack of management sensitivity to the special needs for reliable bulk power supply for the city of New York and for prompt restoration of service in the event of a major interruption. These include—

(1) Inadequate urgency in assuring prompt repair of the phase-angle-regulating transformer on the Hudson/Farragut tie, which was unavailable on July 13, 1977[1]

(2) Failure to assure the availability of substantial amounts of quick-start generating capacity, some of

[1] For a description of considerations surrounding the unavailability of the Hudson/Farragut intertie, see Statement of Charles B. Curtis, Chairman, Federal Energy Regulatory Commission, before the Subcommittee on Energy and Power, Committee on Interstate and Foreign Commerce, House of Representatives, October 13, 1977, pp. 34–41.

which was unmanned and some of which was under inspection at the time of the emergency

(3) Lack of adequate provision for assuring proper performance of system operators under conditions of stress

(4) Lack of adequate provision for assuring the use of appropriate communication methods, for assuring that channels of authority were clear, or that critical information would be promptly exchanged under emergency circumstances

(5) Lack of adequate testing of emergency power supplies

(6) Design of certain transmission facilities in a manner that does not reflect full appreciation of the need to minimize the possibility of service interruptions

(7) Failure to assure proper performance of the automatic load-shedding mechanism

(8) Failure to make provision for adequate, up-to-date, comprehensive plans for restoration of service after failure of the system

Recommendations

Con Edison must give increased and sustained top-management attention to matters affecting reliability and emergency preparedness. A program should be instituted that will regularly confirm that the system is being operated well within adequate reliability criteria and that personnel and facilities are in readiness for emergencies. There should also be a program, emanating from the company's highest management levels, to create throughout the organization an increased sense of awareness and urgency regarding the possibility of emergency situations, their severe consequences, and the need for planning and preparation to mitigate their effects.

CONTROL CENTER AND COMMUNICATIONS

Conclusions

At the time of the July 1977 power failure, Con Edison's control center was not equipped with the most modern display and control technology. However, the equipment was adequate to provide the basic information and control functions required. One class of important information, specific transmission-circuit in-service status, was not displayed explicitly; it had to be derived by the operator from line-power-flow data.

The arrangement of controls for manual load shedding may not have provided a clear, unambiguous basis for operator actions. A master switch was installed to provide for load shedding in one position and for a different system control function in another. There are indications that the system operator's failure to effect manual load shedding may have resulted from making the attempt with the switch in the wrong position. Also, there was no specific provision for simultaneous shedding of large blocks of load. Nevertheless, load-shedding controls were available, and operating personnel had been trained in their use.

Internal and external communications facilities were adequate both as to type and design.[2] However, during the period of increasing emergency, these facilities were not used effectively. During an extended period neither the New York Power Pool (NYPP) operator nor operators in neighboring systems were able to reach the Con Edison system operator. The NYPP "hot line" could very probably have overcome this breakdown in communications, but it was not used. The transcripts of telephone conversations (see app. D) during the critical period contain imprecise terminology and jargon and are especially marked by lack of acknowledgment of information received and understood.

After the failure, communications were hampered by lack of emergency power supply. During this period, however, commercial telephone facilities were used effectively, and there was no significant delay reported in the restoration of service as a direct result of communication problems.

Recommendations

(1) In the control center, a dynamic line loading and outage display board should be provided that would provide operating personnel with rapid and comprehensive information about the facilities available and the operating condition of each facility in service.

(2) The control center should have the capability to display to the system operator computer-generated alternative actions specific to the immediate situation, together with expected results of each action.

(3) Comprehensive analysis of all present man-machine interfaces should be undertaken to determine where unnecessary or overly complicated demands that could be assumed by automated equipment are now imposed on system operators and where it is possible to provide the operator with better organized and better aggregated data to facilitate accurate and timely decisionmaking. The control center should be modified accordingly.

(4) Con Edison should install load-shedding controls to allow single-action activation of large-block load shedding. The controls should have the flexibility to permit operating personnel to make rapid adjustments after shedding large blocks of load.

(5) There should be significantly more redundancy in telephone equipment at the system operator's station, with indicators to show calling source and degree of urgency.

(6) Specific nomenclature should be established for

[2]A detailed description of Con Edison's internal communication facilities is given in appendix K.

communications between the operating offices of NYPP member systems and the NYPP operating center.

SELECTION, TRAINING, AND SUPERVISION OF OPERATORS

Conclusion

The single most important cause of the July 13, 1977, power failure was the failure of the system operator to take necessary action. The Con Edison system could have survived the lightning-induced line outages, the loss of the Indian Point No. 3 generator, and the equipment malfunctions that extended the impact of these events. It could not have survived these events, however, without either some load shedding or prompt increase in in-city generation. The system operator, the only person authorized and able to take these actions, did not call for increased in-city generation at the proper time and did not initiate manual load shedding until too late, although repeatedly advised or directed to do so and even when that action became the last hope of averting a major interruption.

Con Edison's selection of system operators, as practiced before July 1977, was such as to assure that persons in these positions had sufficient experience to be fully familiar with the behavior of the system under various conditions, with the control center information displays, with the control functions and devices, and with the procedural requirements and authority of the position. Con Edison's training program for system operators covers these same matters in detail. The failure of the system operator to take proper action on July 13 indicates that the training and testing program lacks provision for assuring proper system-operator performance under stress and casts doubt on the adequacy of the training program as it relates to equipment, procedures, and decision criteria to be employed during emergencies.

Recommendations

(1) Con Edison should make a thorough reevaluation of its selection and training of system operators.[3] Selection should involve a sufficiently large pool of candidates to permit selection of persons who not only have the requisite experience, but also have superior qualities of leadership, decisionmaking, and performance under stress. Training for positions in the system operator job ladder should develop skills in decisionmaking, command and control, and crisis management and should provide an environment in which both trainees and supervisors can evaluate attitudes and behavior relative to these skills.

(2) A full scale simulator should be made available to provide operating personnel with "hands on" experience in dealing with possible emergency or other system conditions.

(3) Employees should be examined periodically on their knowledge of the operating procedures, particularly those that apply under emergency conditions.

(4) System operating personnel should be physically and psychologically tested at regular intervals to assess stress and physical performance levels.

(5) System operator training should include attention to the use of precise terminology, the avoidance of ambiguous or superfluous description, and the need for acknowledgment of messages.

(6) System operating personnel should be given periodic retraining in the operation of load-shedding equipment.

(7) Redundancy, or backup protection, should be provided for the system operator function, in the form of an additional employee who would not be involved in normal minute-to-minute operations, but who would be in a position to oversee system conditions specifically with reliability considerations in mind, to anticipate contingencies, and to take over actual operations in an emergency.

(8) Under Federal sponsorship, a program should be developed to establish criteria for selection of personnel, training, and the evaluation of training methods, together with criteria for control room equipment, operating procedures, and other elements of the man-machine relationships involved in system operations. Consideration should be given to Federal licensing of operators of major power systems operating in interstate commerce.

SYSTEM OPERATING PRACTICES

Conclusions

On July 13, 1977, the Con Edison system was being operated with insufficient attention to established procedures. In addition, the established procedures were deficient in some respects, including failure to account for special hazardous situations, failure to provide for adequate verification of capabilities needed to meet contingencies, and lack of measures to assure effective coordination with NYPP.

NYPP policies require that a specified portion of the operating reserve generation be on automatic generation control (AGC), but Con Edison on July 13 had no generation in such a mode. This control provides for adjustment of the pool generation every 3 seconds to maintain the scheduled levels of imports or exports from or to systems outside the pool. Had Con Edison had units on AGC, the increased pool imports resulting

[3] An independent consultant was employed by the FERC staff to investigate matters relating to the selection, training, and supervision of Con Edison system operators. The consultant's report is presented in appendix E.

from the loss of Indian Point No. 3 would have been compensated partly by increased generation on the Con Edison system, without requiring operator action. This would have improved the condition of the system by the time of the second lightning stroke and reduced the transmission overloads that resulted.

At the time of the first lightning stroke, several combustion-turbine generators had just been shut down because of declining system load and were undergoing routine postoperation inspection. They were, therefore, unavailable when the system operator called for fast load pickup. Their unavailability had not been reported to the system operator or NYPP. Although the unavailability of these units did not reduce the fast-load-pickup capability below the minimum requirement of the pool, it did represent a considerable portion of the amount by which the generation pickup failed to meet expectations. Had the unavailability of the units been known, the system operator might have attempted load shedding at an earlier time.

The computer-directed economic dispatch of pool generation can operate to increase transmission overloads after a contingency, by assigning generation to more economic upstate units instead of to Con Edison's units. Provisions to prevent such adverse control actions from occurring during contingency situations are lacking.

Although transmission line outages can result from a variety of causes, lightning is responsible for more outages than all other causes combined. Because of the short (few hours) exposure times associated with the lightning hazard, there is only a relatively small cost incurred by reducing transmission imports during lightning storms so as to provide a safe margin for multiple contingencies. Operation of the Con Edison system should be adjusted to compensate for the increased hazard to transmission during thunderstorms, because the experience of July 13, 1977, and another series of incidents on September 26, 1977,[4] show that the probability of multiple line losses during such storms is not insignificantly small.

At the time of the July 13, 1977, Con Edison power failure, Con Edison's portion of the coordinated operating reserve within NYPP was about 292 MW of 10-minute reserve and an additional 163 MW of 30-minute reserve. These reserve obligations, in combination with other NYPP members' operating reserves, were to cover the capacity loss of the largest single contingency and one-half of the largest second contingency loss that could result within the pool.[5] Procedures call for replacement of the operating reserve as it is used. Con Edison's operating reserves more than satisfied NYPP criteria at the time of the initial incident on July 13, 1977. However, first- and second-contingency losses on Con Edison's system can potentially exceed 2,000 MW in magnitude. Although composite NYPP operating reserves can cover such losses, the distribution is such that the replacement power will generally tend to overload the transmission system in Con Edison's service area.

The actual response of Con Edison's reserve generation, when called for by the system operator on July 13, was significantly less than the response expected on the basis of information provided to the system operator. Causes included auxiliary-equipment deficiencies at generating plants, failure to report unavailable combustion turbines, and operating problems with certain combustion-turbine units. It is essential that the system operator and the pool operator be able to rely on obtaining the fast-load-pickup response predicted for the stated reserves.

Coordination between NYPP, Con Edison, and other utilities was ineffective in the period between the initial contingency and system separation. Line-outage information possessed by NYPP was not effectively communicated to Con Edison's system operator. The system operator failed to act in response to load-shedding instructions from NYPP. Some actions taken by Long Island Lighting Co. were not helpful, because they were not matched by coordinated Con Edison actions. However, although better coordination would have reduced the extent of the overloads, the basic needed corrective action—load shedding—could only be accomplished by the Con Edison system operator, who had adequate information and capability to carry out that measure.

Recommendations

(1) Con Edison should institute provisions to insure compliance with NYPP Operating Reserve Policy (OP-2-7) with respect to the amount of generation that is on regulation (AGC).

(2) Con Edison should have an operating reserve policy that provides for 10- and 30-minute reserves to cover the largest first and second contingencies, respectively, on its own system, instead of relying on NYPP to provide a portion of the reserves.

(3) Con Edison's operating-reserve policy should include provisions for prompt mandatory accounting of generating unit status to the control center.

(4) More frequent testing and demonstration of fast load pickup of generation (availability of 10-minute reserve) should be made a standard procedure.

(5) The NYPP economic-dispatch computer security override program should be changed to modify economic dispatch in any situation where overloaded facilities have not been returned to normal ratings.

(6) Operating-reserve distribution among NYPP

[4]The September 26, 1977, incident is described later in this chapter. It involved lightning-induced line outages and significant loss of generation, but did not lead to a systemwide failure.

[5]A discussion of operating reserve policy is contained in appendix I.

systems should be reexamined in view of available system import capability.

(7) NYPP and its member utilities should study means of assuring coordinated actions during emergencies, which would include establishment of clear procedures for communication, definition of channels of command, consideration of alternatives, specific assignment of responsibility, and confirmation of actions taken.

DESIGN, OPERATION, AND TESTING OF PROTECTIVE SYSTEMS

Conclusion

The two events that initiated the July 13, 1977, power failure were of the same nature; each consisted of simultaneous lightning-induced faults causing outages on two 345-kV transmission lines that were separate circuits but were carried on the same towers. Under Con Edison's system reliability criteria, the second of these events was considered to be a single contingency that the system was designed and operated to withstand without loss of load. The first was considered to be a double contingency. According to Con Edison's records, only two similar lightning-induced double-circuit outages had occurred in the previous 15 years. A similar series of strokes occurred on the Con Edison and two adjoining systems less than three months later, with more severe impact than those of July 13. The latter event required prompt action, including the shedding of 325 MW of customer load to prevent a recurrence of the July 13 incident. At one time during this latter incident, four circuits were out of service because of lightning strokes. The occurrence of these events calls into question the effectiveness of the lightning-protection provisions on the transmission lines connecting Con Edison to adjoining systems.

A contributing cause of the July 13, 1977, failure was that simultaneous opening of breakers at Buchanan South Substation, required to clear the lightning-induced faults on the W97 and W98 transmission lines, disconnected Indian Point No. 3 from its load, causing it to shut down, and disconnected line Y88 from Ladentown Substation. Further, although normal relay operation would have restored Y88 within a matter of seconds, the relay scheme used to protect breakers at Buchanan South was so designed that it responded improperly to the breaker operation at Buchanan and tripped the Ladentown breakers unnecessarily. It is clear that although the Buchanan South circuit breaker arrangement is extremely important with respect to Con Edison's capability to bring in power from its own and other plants west of its service area, the arrangement in place in July 1977 was of questionable design. This is true also of the Pleasant Valley breaker arrangement.

Other contributing causes of the July 13, 1977, power failure were malfunctions of two items of protective equipment, a circuit breaker and a relay, both at Millwood West Substation. A loose locking nut on a control valve linkage prevented a proper and vital reclosing of a breaker on the W98 345-kV line at Millwood at the time of the first incident. The W81 345-kV line from Millwood West to Pleasant Valley was tripped unnecessarily by a relay malfunction. The relay was later discovered to have a bent contact.

Currently, certain of Con Edison's critical transmission lines, including interconnections to other systems, are subject to severe and possibly damaging overloads under emergency conditions, if operator action to reduce power flow is not taken promptly. No automatic protection is provided for overload below fault levels.

During the restoration period, a number of relay operations caused second interruptions in restored areas. The FERC staff found that some of these operations were inconsistent with operating procedures for restoring sections of transmission circuit.

Recommendations

(1) Con Edison should make a critical review of the lightning performance of its major 345-kV transmission lines. The tower footing resistances should be remeasured to assure that resistances are satisfactory.

(2) The breaker arrangements at Buchanan South and Pleasant Valley Substations should be redesigned to provide a greater degree of independent isolation among the associated transmission lines.

(3) Con Edison should make a critical review of all extra-high-voltage (EHV) relay schemes, including clearing times and synchronism-check-relay permissive-closure angles, to assure that reclosing at remote line terminals is prevented when there is a stuck breaker. All EHV line breakers should be installed with provision for multiple reclosure.

(4) Relaying systems for transfer tripping or lockout that involve timers should be installed so that timers are activated through circuit-breaker contacts.

(5) System trip tests of relay schemes should be performed periodically. At installation the acceptance test should be performed on the complete relay scheme in addition to each individual component so that the adequacy of the scheme is verified.

(6) Electrically reset auxiliary relays should be employed in transfer trip protective systems so that substation operating personnel at the substation initiating the trip signal can assess and clear the damaged equipment and then reclose the remote breakers.

(7) To minimize the likelihood of improper adjustment of protective equipment, Con Edison's inspection procedures should include periodic unscheduled and random inspection and checking of equipment to verify testing and maintenance quality.

(8) Con Edison should install sensing devices on critical transmission lines to shed load automatically if the short-time emergency rating is exceeded for a

specified period of time. The time delay should be long enough to allow the system operator to attempt to reduce line loadings promptly by other means.

(9) Interlocks, sensitive to insulating-oil pressure, should be installed to prevent energization of transmission cables when the oil pressure is below the required minimum.

(10) Instances of the loss of restored areas as a result of inappropriate equipment operations, e.g., relay operation in loss of the Queens transmission and ground switch operation in loss of Richmond transmission, should be thoroughly examined to determine what changes are required to eliminate recurrence of such events in the future.

A brief discussion of factors involved in lightning performance of transmission lines, with data on Con Edison's experience with its 345-kV lines, is given in appendix F. A detailed evaluation of relay operations during the July 13, 1977, disturbance is given in appendix G. A description of Con Edison's testing and maintenance program for protective devices is given in appendix H.

EMERGENCY PLANNING AND OPERATIONS

Conclusions

The events of July 13 and 14, 1977, show many instances of deficiency in Con Edison's planning for emergencies and in the degree of readiness of equipment and personnel.

The most important lack of personnel readiness was in the control center. The record of telephone conversations and other data indicate that the Con Edison system operator made an incorrect evaluation of system status and did not take the corrective measures required.

Automatic underfrequency load shedding, a function designed to be a last resort to prevent total collapse of the isolated system, operated as it was designed to do, but failed to prevent collapse, because voltage surges caused protective devices to trip major generators off the line. It may be impractical to arrange a full-scale test of underfrequency load shedding, and the computer simulation of a load-shedding sequence on even a part of Con Edison's system would be very difficult. However, even a limited simulation should have provided some warning of voltage transients.

Con Edison had, in July 1977, specific procedures for system restoration. In some cases, however, the procedures were out of date, not sufficiently detailed, and ambiguous. The unsuccessful attempt at rapid restoration was made without benefit of adequate procedures.

Testing of emergency functions was clearly inadequate. Emergency power supplies were insufficient and some were not in working order, indicating that there had been little attention to this vital equipment. The main and backup power supplies for UHF communication stations failed to operate. There was widespread loss of cable oil pressure, and very limited emergency pumping power to restore the required pressure.

The combustion-turbine generators identified as black-start units, vitally needed for early generation in the restoration, failed to start as expected in almost all cases. The combination of these factors delayed the restoration very significantly.

Recommendations

(1) Con Edison should include in its written procedures and in its training for system operators adequate treatment of anticipation, recognition, and definition of emergency situations.

(2) Procedures should be more specific as to conditions requiring 10- and 30-minute reserve generation and manual load shedding.

(3) The adequacy of Con Edison system programs for automatic load shedding should be reassessed with careful analysis of voltage and frequency effects on the load and on the transmission system. The analysis should include consideration of automatic voltage compensating devices to operate simultaneously with automatic load shedding to effect voltage control.

(4) The concept of rapid restoration of major load areas after system collapse should be thoroughly evaluated. If it is an effective approach, it should be supported with detailed procedures. If it is generally unlikely to succeed, operating personnel should not be permitted to attempt it.

(5) Provision should be made for more frequent and more thorough testing and maintenance of emergency power supply facilities. Additional emergency power units should be made available, either as portable units or permanently installed, as appropriate. Emergency power supplies for insulating-oil pumps should be installed.

(6) Combustion-turbine units identified as having black-start capability should be tested at regular intervals under conditions closely matching those of complete shutdown.

(7) Restoration procedures should be brought up to date and revised to assure adequate detail and freedom from ambiguity.

SYSTEM PLANNING

Conclusions

The July 13, 1977, Con Edison power failure was a failure of control and operations rather than one of planning and design. Nevertheless, because the failure so emphasized Con Edison's dependence on its interconnections, a reexamination of system planning and reliability criteria related to the interconnections, as well as to Con Edison's own 345-kV ties to the interconnecting points, is essential.

Con Edison plans to meet its increased load over the next two decades primarily by increasing its ability to transfer power into its service area from sources outside the area. Some of these sources may be owned by Con Edison, but, in any case, there will be increased reliance on transmission facilities. Studies of Con Edison's transmission requirements (see app. L) indicate that the company's plans are reasonable in terms of the forecast load growth.

New transmission facilities will also be required within Con Edison's service area. Much of these transmission facilities will be underground, which will add to voltage control problems and increase the need for compensating devices. The prospect of increasing reliance on transmission into the city of New York will require greater attention to transmission hazards, to assuring the proper operation of transmission protective systems, to the circumstances in which load shedding will be employed to maintain system integrity, and to the methods by which load shedding will be effected. The system must be planned to provide the essential degrees of facility redundancy, emergency corrective measures, operator control, and automatic functions needed to avoid system collapse under adverse conditions.

Because of the geography of its load area, Con Edison's principal overhead transmission interconnections to NYPP are concentrated in a north-south corridor in Westchester County. Close grouping of any facilities increases the probability that a single event could incapacitate more than one facility, and there has been criticism of the Con Edison transmission configuration on this score. However, Con Edison's citations of line outages since 1962 indicate that there were only two double-circuit outages due to lightning, in spite of the close grouping of major lines. This suggests that the close grouping of transmission lines is not a major factor in Con Edison's system reliability. Reliable performance of the protective circuit-breaker systems and maintenance of diversity of the line terminations, so that all do not connect with the same neighboring utility, are generally more important. It is concluded that increasing the capacity of the northern transmission corridor, in association with other planned transmission additions, will be acceptable from a reliability standpoint provided that proper design is followed for related substations and protective equipment.

There are implications in the Con Edison statements and reports that its inability to plan and construct its system with additional generation near the load center was a significant factor in the problems of July 13 and 14 and will lessen the system's reliability in the future. It is generally recognized that a system with generating units close to the load center tends to be more flexible and resistant to transmission contingencies and, from this standpoint, more desirable. However, environmental and other factors generally restrict the construction of power plants in metropolitan areas everywhere, not just in New York, and system planners can provide adequate reliability levels through measures such as transmission redundancy, protective equipment, and load-shedding capabilities. On July 13 Con Edison had sufficient unused in-city generation to carry its load at the time of the initial incident. It is concluded that the necessity for Con Edison to plan its system without additional in-city generation was not a significant factor in the collapse and should not prevent the maintenance of adequate reliability levels in the future.[6]

Con Edison's evaluation of contingencies for transmission design and establishment of operating procedures is generally consistent with industry practice. The multiple outages resulting from the first two incidents on July 13, 1977, would be considered, under accepted industry criteria, a highly improbable event. Double-circuit flashovers are not common, and failure of three of the four affected lines to reclose following fault-clearing would not be expected. The two 345-kV circuits from Buchanan South to Millwood West, even though carried on the same towers, were separated by the full tower width (approximately 72 feet) and had two 138-kV lines suspended between them. Nevertheless, these two circuits are extremely important elements of Con Edison's bulk power system. The judgment to treat their simultaneous outage as a low-probability double contingency, which the system would not be designed to fully withstand, is at least questionable in view of the extreme sensitivity of the city of New York to the failure of its power supply.

Recommendations

(1) Con Edison should reevaluate its definitions of single and double contingencies, with appropriate consideration of its degree of dependence on certain key facilities, and of the special risks and economic losses associated with service interruptions on its system.

(2) Con Edison should give additional attention to assuring the availability of key substations that are crucial for importation of power generated outside the city, such as Buchanan and Pleasant Valley. The design of breaker arrangements and protective relaying at such stations should be upgraded as power imports increase.

COMPLIANCE WITH RELIABILITY RECOMMENDATIONS

Conclusions

Since 1965, and before July 13, 1977, some 35 State and Federal electric reliability recommendations were

[6]It is evident that continued growth of the Con Edison system would require additional transmission lines, if in-city generation continues to be restricted.

made having specific reference to Con Edison's operations. In the great majority of cases, the company has fully or substantially complied with the recommendations. In no case has the company ignored the recommendations.

Between July 14 and September 30, 1977, an additional 30 recommendations were made by the Federal Power Commission (FPC) and the New York Public Service Commission (NYPSC). Most have been or are in the process of being implemented by Con Edison. Some have been rejected on the grounds of impracticality or excessive cost in relation to benefits, but all have been considered.

Recommendations

Con Edison and NYPP should provide periodic reports to appropriate regulatory authorities on their implementation of recommendations made by the several investigating bodies. The reports should include analyses of the effectiveness of the actions taken, information on the results of unscheduled system emergency simulations, audits to evaluate the readiness of the system to withstand emergencies, and proposals for alternative measures that appear more practical or cost effective.

ACTIONS TAKEN BY CON EDISON SINCE THE FAILURE

After the restoration of service to all customers of the Con Edison system, the company took steps to ascertain the causes of the failure and to assess the measures necessary to prevent recurrences. The company created its Board of Review, consisting of a number of its executives and several consultants. President Carter directed FPC to investigate the failure. In addition, investigations were initiated by the city of New York, NYPSC and the State of New York, as well as by committees of the Congress. On August 4, 1977, the FPC staff issued a preliminary report containing a series of recommendations; recommendations have also been made by NYPSC, the city of New York, and the State of New York.

A number of actions have been taken by Con Edison on the basis of its own investigation and in response to these recommendations. These actions fall into four general categories:[7]

(1) Measures to strengthen the system control function, including—

(a) Addition of a storm watch coordinator to the control center and establishment of special operating procedures for storm conditions

(b) Addition of a position of senior district operator to the control center to coordinate all switching operations for the system operator

(c) Improvement of information displays for the system operator and simplification of the manual load-shedding controls

(d) Establishment of a regular program of physical and psychological testing of control personnel

(2) Measures to increase system readiness for emergencies, including—

(a) Limitation on importation of power during thunderstorms

(b) Round-the-clock manning of gas-turbine generating units until remote startup capabilities are established

(c) Regular testing of emergency power supplies and black-start capability

(d) Monthly fast-load-pickup tests on all generating units

(3) Measures to strengthen interties with other systems, including the return to service on October 14, 1977, of the Hudson/Farragut 345-kV tie, without the phase angle regulator, made possible by the implementation of forced cooling of several in-city underground cables, which increased the transmission-cable capability

(4) Revision of system design and operating concepts, including—

(a) More specific procedures for use of manual load shedding to relieve tie-line overloads and to avoid separation from other systems

(b) Use of automatic load shedding to relieve tie-line overloads if operator actions are insufficient

(c) Use of more stringent criteria for transmission-line protective system design

Some of the actions taken contributed in important ways to the ability of the Con Edison system to withstand another serious set of contingencies on September 26, 1977. On that day, the Con Edison system was again subjected to a series of lightning strokes that impacted system facilities more severely than the ones that resulted in the July 13 power failure. Over a period of about 1 hour 13 minutes, lightning strokes and related events resulted in the loss of eight transmission lines and four large generating units. This time, however, the energy control center had initiated the new Thunderstorm Contingency Procedure, which included—

(1) Termination of any wheeling of power to Long Island municipalities

(2) Increase of in-city generation by 100 MW

(3) Adjustment of phase-angle-regulating transformers to reduce interconnection loading to appropriate transfer limits

[7] Appendix N contains a more detailed listing of Con Edison's response to recommendations made by various agencies since July 13, 1977.

Use of this procedure means that the system was prepared to sustain a second and third contingency (e.g., loss of two 345-kV circuits on any single tower) in addition to the assumed first contingency. Within 9 minutes of the first lightning stroke, nevertheless, systemwide 8-percent voltage reduction was employed to reduce load by 272 MW. During the next 19 minutes, 325 MW of load at three substations in Westchester County was shed manually from the energy control center. Service was completely restored within 1 hour 5 minutes of the original lightning stroke and within 47 minutes of the time load was shed.

The FERC staff believes that the actions that have been taken by Con Edison to date are commendable. It is expected that the company will continue to pursue further improvements on the basis of its own studies and of the recommendations presented earlier in this chapter. An open and aggressive program toward these ends on the part of Con Edison's management, coupled with careful oversight by the appropriate regulatory authorities, will provide the best assurance of reliable electric service to Con Edison's electric power customers.

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Chapter VIII

OTHER INVESTIGATIONS OF THE BLACKOUT

Four other investigations of the events of July 13 and 14 have been conducted, resulting in published reports. These investigations are—

(1) The investigation of the New York Public Service Commission (NYPSC) Staff Task Force which issued reports in August and September 1977

(2) The investigation of the New York City Special Commission of Inquiry, which issued its report in early December 1977

(3) Con Edison's own investigation, covered in its first-, second-, and third-phase reports, the last of which was issued early in January 1978

(4) The investigation of the State of New York, which issued its report late in January 1978

There are broad areas of agreement among the findings of the several investigations, as well as some significant differences. The agreement is strongest on the specific technical factors involved in the collapse and slow restoration. There is more divergence, however, on judgmental topics, for example, (1) what should have been known in advance, (2) the adequacy of design and operating practices, (3) the role of facilities not built or out of service in contributing to the collapse, and (4) the need for restructuring electric power institutional relationships.

In this chapter, the principal findings of the city, State, and company investigations are summarized and compared with those of the investigation begun by the Federal Power Commission (FPC) and completed by the Federal Energy Regulatory Commission (FERC). FERC staff comments are provided on significant differences. The NYPSC Task Force findings and the report of the special State investigation (Clapp Report) are considered together, because they appear to represent separate phases of the investigation at the State level.

THE CITY REPORT

In December 1977 the New York Special Commission of Inquiry, established by Mayor Beame, issued its report on the blackout. The city report concludes that the system collapse and slow restoration were primarily attributable to Con Edison's failure "to use available technology, or voluntarily institute recommended improvements, necessary to plan, design, operate and maintain a system capable of avoiding collapse due to such predictable occurrences." It states that critical weaknesses in the bulk power system "were clearly anticipated by the Federal Power Commission and the [N.Y.] Public Service Commission in recommendations—published after the 1965 Northeast power failure. However, just as Consolidated Edison failed voluntarily to undertake those recommendations, these agencies failed to mandate their implementation." It states that "the inability of Consolidated Edison to construct additional generating facilities in its load centers was not a significant factor contributing to the power failure," that Con Edison "was importing too much power on July 13, 1977 . . . [and] . . . violated reliability council criteria for reliable system operation," that "relaying and protective circuit design, testing and maintenance practices are deficient," that facilities at the company's energy control center are "obsolescent," and that "the failure of the Company's operator to take timely and appropriate action . . . is the responsibility of the management of the Company, which did not provide its operators with adequate operating directives, training and display equipment," that Con Edison "failed to pre-study restoration of a collapsed system and to develop a written plan for restoration," and that the company "failed to install adequate back-up for pressurizing oil lines . . . [a] necessity . . . specifically recommended by the Federal Power Commission in 1967."

The city report finds that Con Edison's management and the regulators (NYPSC and FPC) must share the responsibility for the collapse and slow restoration. "It is plain beyond doubt that the system collapse of July 13–14 could have been averted and full restoration of that system substantially accelerated, had Consolidated Edison's management, voluntarily, or through the vigilant oversight of either the Public Service Commission or the Federal Power Commission, earlier implemented many important recommendations those regulatory agencies made subsequent to the 1965 Northeast power failure."

One of the principal recommendations is that "to stimulate Consolidated Edison's management to greater action and concern for system reliability," the company's board of trustees should include members appointed by the Governor, the mayor, and the Westchester County Executive. The city report also recommends that NYPSC be granted explicit jurisdiction over the New York Power Pool (NYPP) to compel compliance with reliability measures judged desirable, that NYPSC begin proceedings to order Con Edison to implement specific recommendations, and that FERC authority be expanded to enable it to resolve disputes among utilities over interconnection issues, such as timing, location, and size.

The FERC staff findings regarding the specific events that led to the system collapse and that caused the delays in system restoration are generally in accord with those of the city report. Also, the staff agrees with the city report in specifically questioning the design of the Buchanan Substation regarding protective-equipment arrangement and the design of associated relaying.

The staff does not agree with other findings of the city report, however, in several important respects. First, it disagrees with the city report finding that the company was exceeding import limits established by criteria of NYPP and the Northeast Power Coordinating Council (NPCC), although the company did fail to have generation on automatic control as specified by NYPP.

Second, the staff did not find significant deficiencies in system planning or clear-cut violations of existing contingency criteria. However, Con Edison's decision not to consider loss of both lines W97 and W98 as a single contingency was not a cautious decision. In the staff's view, Con Edison should design its system to be well within stringent interpretations of NYPP contingency criteria. Nevertheless, on July 13 Con Edison had sufficient unused in-city generation to carry its load at the time of the initial incident. The out-of-service status of the Farragut/Hudson interconnection was a known constraint and there was adequate capability, with proper operation, to deal with improbable contingencies through increased generation and load shedding to prevent system collapse.

Third, staff does not agree that deficiencies of the control center equipment contributed significantly to system collapse. Although the Con Edison control center is not of the most modern design, and although improvements will enable operators to determine the status of equipment more quickly and comprehensively, the information and control capability available in the control center on July 13 was adequate for experienced operators to evaluate the situation and take appropriate corrective actions.

Fourth, the city report declares that the company failed to prestudy restoration planning. The staff found that the company had expended considerable effort on such planning. Its written procedures were of significant assistance, although some of them were out of date, incomplete and sometimes ambiguous.

The city report states that Con Edison had shown a pattern of inadequate compliance with reliability recommendations made in the past by FPC and NYPSC and was generally insensitive to reliability considerations. The FERC staff finds that Con Edison has not ignored any of these recommendations and has complied with the great majority of them.[1] In some cases, Con Edison's decisions and adoption of measures to protect against particular hazards now appear to be questionable, but all the hazards identified in the regulatory-body recommendations appear to have been considered. A particular point is made by the city report about the Con Edison decision not to provide auxiliary oil-pumping capability for its underground cables, even though Commonwealth Edison, serving Chicago, had provided such a capability for its system after the 1965 blackout, a fact noted in the 1967 FPC report. The FPC report, however, used the Commonwealth Edison action as an example of the need to evaluate the unique and special requirements of individual utility systems; the mention of the action was clearly not a specific recommendation that utility systems in general or Con Edison in particular install auxiliary pumps for this purpose. On the basis of tests, Con Edison determined that the cables would hold adequate pressure for 4 hours without pumping and concluded that this would provide sufficient time, in conjunction with sequential reenergization of the transmission network, to restore power supply to the pumps without disrupting satisfactory system restoration. The experience of July 13 and 14 indicates that this was an incorrect conclusion; the lack of cable pressure did become a major factor in delaying total system restoration. The staff considers that Con Edison management must accept responsibility for inadequate testing and an incorrect decision, but not for ignoring a specific FPC recommendation.

Finally, the city report essentially concludes that the deficiencies revealed by the July 13 and 14 experience were basically attributable to the profit-oriented attitudes of top management. The FERC staff investigation did not disclose evidence to support this conclusion. In the staff's view, Con Edison management should be criticized for a general complacency and inadequate attention to specific needs, not for deliberate profit-related compromise of service reliability. It is clear that various levels of service reliability can be provided by any electric utility at various levels of cost, and that the consumers who must pay the rates for electric service are the same consumers who must be satisfied with the

[1]Appendix O lists the recommendations made after the 1965 Northeast power failure and shows the extent of compliance by the company with each.

level of reliability that can be supported by such rates. It is important that consumers be aware of this relationship; it is also important that the company and the agencies that regulate its rates find ways to inform themselves of the level of reliability that consumers want and are willing to pay for. The staff believes that there are ways to achieve this objective through careful and consistent regulatory oversight, which would be more effective than the addition of public members to the company's Board of Directors.

THE STATE REPORTS

The NYPSC Task Force issued reports on its investigation on August 3 and September 17, 1977. It finds that although the Con Edison system has changed since 1965 from one using predominantly in-city generation to one having major generating units north of the city and regularly importing large amounts of power from the north, its imports on the night of July 13 were found to be within the transfer limits based on NYPP calculations. It states that multiple contingencies occurred on July 13 that were more severe than the criteria by which the Con Edison system was designed. Consequently, it recommends studies to determine whether designing for double contingencies is needed for the Con Edison system, whether the north-south transmission capacity is sufficient for Con Edison's mode of operations, and what measures are needed to prevent widespread system disruption when multiple contingencies occur.

Back flashover was found to be the probable cause of the transmission-line faults that led to the July 13 failure. Incorrect relay operations and possibly unnecessarily restrictive synchrocheck relay settings were found to have caused circuit breakers to open erroneously and a circuit breaker to fail to reclose. The report questioned the design of the Buchanan ring-bus arrangement, as compared to a "breaker and a half" configuration. Consequently, the report recommends studies and measures to improve the lightning resistance of Con Edison's transmission lines, a complete reevaluation of the company's policy on breaker reclosing and relay settings and a new study of the switching and protective arrangements at the Buchanan Substation and Pleasant Valley Substation.

The NYPSC report found that the improved control center is not scheduled to be available until 1981, and in the meantime Con Edison's system operators will be forced to make decisions with only limited and poorly displayed information. It notes that a 1975 management study of Con Edison by Arthur D. Little, commissioned by the NYPSC, was critical of deficiencies in the energy control center and, in the study's words, "the process by which management decided not to move forward with improvement of the Energy Control Center." Consequently, the NYPSC report recommends expeditious improvements to the energy control center, additional control center staffing as an interim measure and improved means of indicating line loadings in excess of the short-term emergency ratings. It concludes that failure of the system operator to initiate load shedding, as Con Edison procedures call for, brings into question operator training and experience. It consequently recommends that formal training programs for the company operators and dispatchers be instituted, the benefits of a training simulator be studied, that annual physical and psychological examinations of system operators be conducted, and that NYPP establish a system-operator certification program.

The NYPSC report questions the ability of Con Edison to shed load rapidly enough in an emergency. It recommends that the speed of manual load shedding be increased and that a reevaluation be made of the company's reliance on automatic load shedding as a "last line of defense." It is also critical of the poor quick-start performance of Con Edison's combustion-gas-turbine generators, despite their inherent capabilities, and recommends restoring a remote start capability for some or all of these generators and a restudy of the role that they should be assigned in allocating operating reserve and meeting system emergencies. The report notes the problems experienced in communications and joint actions between Con Edison and the NYPP on July 13 and recommends strengthening reserve reporting requirements, establishing specific terminology to avoid possible ambiguity in NYPP orders, clarification of actions to be taken to relieve transmission-line overloads and establishment of procedures to restore the 10-minute reserve after an emergency.

These detailed NYPSC Task Force findings and recommendations generally paralleled those developed by the FERC investigation and by Con Edison. They address specific design and operating issues and do not include institutional questions. Many have been implemented or initiated by the company.

The final report of the State of New York Investigation (Clapp Report), issued in January 1978, extended the evaluations of the NYPSC Task Force to include the events of September 26, 1977, with particular emphasis on transmission design and operations. It did not examine the restoration experience, but did consider institutional matters in relation to the reliability of the New York State bulk electric power supply.

The report states ". . . the root causes for the inability of the Con Edison system to withstand the impact of the storm and continue to function go much deeper than mere bad weather. . . . They are to be found in deficiencies of system planning and design, the unavailability of vital facilities, a lack of unified command and coherent action under emergency conditions, mechanical failure and operational error." In more detail, the report states that—

(1) The availability of either the out-of-service

Hudson/Farragut tie or the gas-turbine units would have prevented the blackout.

(2) A key weakness is the reliance on a narrow transmission path to the north.

(3) There were important shortcomings in transmission and switching design, notably the configuration at Buchanan Substation, which causes shutdowns of the Indian Point No. 3 generating unit after temporary transmission interruptions and takes out one of the Hudson river crossings when the lines from Buchanan to the city are lost.

The design is said to "show both compromise and a straining of Pool reliability criteria to their limits or beyond." The report characterized the overall planning and design of the bulk-power-transmission system in New York as having been compromised by the financial limitations of the individual utilities, resulting in "a significant sacrifice of essential reliability" and "the dangerous preoccupation of Con Edison with its transmission corridor to the north aimed in part at procuring larger amounts of what is presently less expensive Canadian hydroelectric power."

The report says that a number of the equipment failures that played a role in the events of July 13 and September 26 "should not have occurred under proper testing and maintenance procedures." It finds that there was a lack of coordination and direction between NYPP and the utilities, so that a plan of action that could have averted the blackout was not implemented. It states that massive automatic load shedding cannot be depended upon as the last line of defense, and Con Edison's reliance on it was the consequence of "a general failure to think through the problems that transmission losses can create." It finds that NYPP does not exercise effective control of the factors affecting system reliability.

It recommends that the NYPSC, itself, establish reliability criteria and procedures for Con Edison's bulk-power-transmission system, and general reliability criteria for all members of the NYPP, covering equipment maintenance and testing, cooperation in emergencies, dispatch center design, and standards for operator training and qualification. Finally, it recommends that the State of New York establish a single entity to be responsible for the planning, design, development, maintenance, and operation of the bulk-power-transmission system in the State of New York.

The FERC staff agrees with most of the State findings on the factors involved in the system collapse,[2] but in some instances it assigns them a different degree of importance. For example, facilities that were known to be unavailable, such as the Hudson/Farragut tie although perhaps significant as an indicator of management complacency relative to possible system failure, are considered to be less significant as an immediate causal factor in the July 13 event, because system operations had been modified to conform to the reliability criteria. However, incorrect information as to the availability of certain facilities, such as the combustion turbines, were clearly significant. As discussed earlier, the FERC staff also assigns a minor role to control room equipment deficiencies, because experienced operators should have been able to assess the status of the system.

The FERC staff found that although the Con Edison test and maintenance program for protective equipment was well conceived and carried out with diligence, the faulty equipment exposed by the events of July 13 indicates the need for improvement in certain specified functions. Such need for improvement is reinforced by the findings of the State investigation of the events of September 26, together with those of July 13.

A key point in the Clapp Report is its finding that Con Edison resorted to an unrealistic interpretation of reliability criteria to avoid recognizing the double-circuit outage of lines W97 and W98 as a single contingency. Had Con Edison recognized such an outage as a single contingency, the report indicates, it would have been required to construct an additional length of transmission line (which it now proposes to do). It would not have needed to employ the protective arrangement at Buchanan Substation that shuts down Indian Point No. 3 whenever both the W97 and W98 lines are temporarily interrupted. Although the FERC staff did not conclude that treatment of lines W97 and W98 was a clear-cut violation of existing contingency criteria, it agrees that it was at best a strained interpretation of the criteria rather than a cautious one.

The Clapp Report expresses concern regarding "reliance on a narrow transmission path running from New York City to the north." In the view of the FERC staff, grouping of transmission lines in a "narrow corridor" is not comparable in importance to the adequacy of protective equipment or the configuration of line terminations. However, in view of the extreme importance of the transmission circuits passing through the Millwood Substation, the staff agrees that further separation of the lines in this area may be justified. The staff believes also that the necessity for heavy reliance by Con Edison on transmission through the northern corridor emphasizes the importance of avoiding extended outages of transmission interties to the east and west. Another concern expressed in the Clapp Report is that the NYPP does not direct and control bulk-power-transmission system design and operation but rather provides only a coordinating function. Different degrees

[2]For example, there is a general agreement based upon all of the investigations of the power failure that massive automatic underfrequency load shedding cannot now be depended upon as a last line of defense for the Con Edison system. The State report emphasizes that this is something that Con Edison should have known earlier and would have, if it had critically examined the problems consequent to becoming isolated. The FERC staff agrees with this conclusion.

of centralization exist in various power pools, from simple planning coordination through centralized bulk power dispatch. As the degree of centralization of pool functions increases, the reliability of any given system becomes more dependent on that of the entire group of systems. This leads to an enhanced need for more central direction of operating practices and reliability criteria. In July 1977, NYPP was in its first few months of operation with central dispatch; previously, each member of the pool had been responsible for its own load dispatch. As the member systems acquire additional experience in coordinated planning and operation, further centralization of transmission design and operation functions can be anticipated. These functions may be centralized to a greater extent in the pool or in the NPCC. There is no evidence to support the contention that the State is the proper authority to specify design and operating criteria, particularly in view of the interstate character of most power pools as well as individual systems.

Finally, the staff agrees with the recommendation that standards for operator qualification and training be established . Although establishment of such standards by the pool would be an improvement over the current state of affairs, staff believes that the interstate character of major power systems and pools calls for Federal sponsorship and oversight of such a program.

THE CON EDISON REPORT

The report of Con Edison, dated December 28, 1977, is the third it has issued on the July 13 and 14 blackout. It covers 12 in-depth investigations conducted to confirm or supplement recommendations made in its earlier reports. In the view of the FERC staff, the three reports constitute a generally satisfactory critical self-appraisal of the company's planning, design, procedures, control facilities, and equipment, as they relate to the July 13 and 14 power failure. Had a searching analysis, of the type now completed, been performed by Con Edison before July 13, at least some of the critical problems and deficiencies would have been identified, and the probability of the failure would have been reduced.

On the basis of the recommendations of the Con Edison reports and the company's corrective actions, it appears that the company now recognizes that a number of significant deficiencies existed before July 13, 1977. They include failure to appreciate the increased vulnerability of the system under conditions of high energy imports during thunderstorms, failure to verify the fast-load-pickup and black-start capabilities of generating equipment, failure to analyze critically system stability after system separation and underfrequency load shedding, inadequate training, selection, and testing of system operators for emergency conditions, undesirable complexity in the manual load-shedding controls, possible ambiguities in communications with NYPP, inadequate testing of emergency power supplies and equipment, and inadequate critical analysis and detailed planning for restoration of a completely collapsed system. These deficiencies identified by Con Edison are in agreement with the findings of the FERC staff's own investigation.

One important result of the company's self-analysis has been an apparent increased awareness within the company of potential problems and needed compensating actions. The various operating changes instituted shortly after July 13, 1977, corrected the principal problems that caused the blackout, as evidenced by the satisfactory response of the system to a comparably severe storm contingency on September 26, 1977. The second storm experience confirms the FERC staff's conclusion that the principal causes of the July 13 system separation were operating deficiencies rather than facility deficiencies.

In its third-phase report, Con Edison proposed a number of longer range corrective actions, beyond those instituted immediately following the blackout. (Some of its proposals are to make permanent certain measures instituted earlier.) The proposed additional measures include a new operating policy that would provide for immediate shedding of portions of the load when tie lines become overloaded, on an automatic basis, if not done manually. This measure, in effect, will increase the probability of service interruption for some customers to provide more protection against total system collapse. The basis for this recommendation is that present analysis and modeling techniques are not accurate enough to provide sufficient assurance that a high-load-density system, such as Con Edison's, will remain stable and not collapse after isolation and massive underfrequency load shedding.

Other proposed additional measures are the installation of a new system simulator to improve training of operators for emergency conditions, coupled with physical and psychological tests of control center personnel; establishment of a new senior system operator position to effect a pilot-copilot relationship at the control center; development of a detailed new reenergization procedure to minimize voltage problems during future restorations; modifying circuit-breaker-reclosing schemes; and establishment of permanent auxiliary power supplies at major substations to insure the maintenance of cable oil pressure in the event of system collapse. These actions proposed by the Con Edison report are consistent with the recommendations contained in this report. Many of them address directly the deficiencies revealed by the July 13 and 14 disturbance and are constructive additions to the measures instituted by the company after the blackout.

The Con Edison report proposes adding transmission facilities for the purpose of strenghtening its northern ties and reducing transmission vulnerability. These facilities include a new double-circuit transmission line using a new right of way from a substation in the Buchanan area to one in the Millwood area, and a short length of new right of way paralleling a section south of Millwood. The latter will provide for increased separation of one of the existing lines from the others. Further, the report recommends early construction of the Cornwall project and a proposed Power Authority of the State of New York (PASNY) generating unit on Staten Island to increase generation close to the load centers. With regard to this last proposal, it is generally recognized that a system with generating units close to the load centers tends to be more flexible and resistant to transmission contingencies and, apart from environmental and other similar constraints, is a more desirable system design. However, system planners can provide adequate reliability levels through measures such as transmission redundancy, load-shedding capabilities, and protective equipment, without requiring generation close to the load centers.

The proposed transmission line over a new right of way between the Buchanan area and the Millwood area appears to provide the design which the Clapp Report contends should have previously existed to meet Reliability Council criteria. With the new line, Con Edison will be able to strengthen the protective design at Buchanan, which played a prominent role in the July 13 events.

In its preliminary report, the FPC staff expressed the view that Con Edison's interconnections with other systems were inadequate, and that the company should advance the completion of its planned additional major ties with Public Service Electric & Gas Co. and with Long Island Lighting Co. Con Edison's position appears to be that the timing of these interconnections should be keyed to its load growth and to the completion of new generating units and transmission facilities by the neighboring systems, and that advancement of the projected completion dates for the transmission lines is not cost effective.

The FERC staff recognizes that the additional interconnections, as with the other major facilities proposed by Con Edison, are not essential to achievement of an acceptably low probability of system collapse, provided the system is operated with due regard for the various contingency possibilities. However, as with the other proposed facilities, they do represent an overall system configuration that is inherently stronger than that in place on July 13. If adequate reliability can be achieved with or without the facilities, the proper choice may become largely an economic consideration.

In summary, the FERC staff considers the Con Edison studies, actions taken to date, and proposed future actions to represent a generally satisfactory response to the problems made evident by the July 13, 1977, power failure.

Appendix A
COMMISSION ORDERS

UNITED STATES OF AMERICA
FEDERAL POWER COMMISSION

Before Commissioners: Richard L. Dunham, Chairman;
Don S. Smith, and John H. Holloman III.

Investigation of Major Power Outage on Entire System of Consolidated Edison Co. of N.Y. July 13 - 14, 1977	))))	Docket No. E-9599

ORDER INSTITUTING FORMAL INVESTIGATION
(Issued July 14, 1977)

The President has directed a prompt and thorough investigation of the blackout which occurred on the evening of July 13, 1977, at about 8:35 p.m., when the electric system of Consolidated Edison Co. of New York (ConEd) was hit by lightning. The lightning caused one 345 KV line from Ladentown to Buchanan to go out of service and at the same time Indian Point No. 3 generator was disconnected from service. In a spreading series of events, another 345 KV line went out of service. Other events followed necessitating severing of all ConEd's connections with other utilities to the North and East and within an hour all ConEd's connections with all other utilities had been severed. Immediately thereafter, the Commission staff undertook preliminary investigation and analysis pursuant to Section 2.11 of the Commission's Regulations under the Federal Power Act.

Massive power blackouts cause severe public health and safety problems and they are intolerable. Since the northeast blackout of November 9, 1965, many steps have been taken by the electric industry to avoid a serious recurrence of that very unfortunate episode.1/ Recent events demonstrate that those preventative measures have been insufficient in ConEd's service area.

1/ On July 19, 1967, the Commission sent to President Johnson a 3-volume report on the Prevention of Power Failures.

DC-A-14

Under Section 202(a) of the Federal Power Act, this Commission is charged with "assuring an abundant supply of electric energy". Section 311 of the Act gives us the authority "to conduct investigations regarding the generation, transmission, distribution and sale of electric energy throughout the United States* * *whether or not subject to the jurisdiction of the Commission."

We note that Mayor Beame of New York City has also asked the Commission to investigate the blackout. We are hereby directing our staff to investigate and prepare a formal report of the causes of ConEd's massive blackout, to report to us in 2 weeks, and to prepare recommendations for corrective action to be undertaken. We hereby direct ConEd, all companies interconnected with ConEd and all personnel of the New York Power Pool to fully cooperate with the Commission's staff in its investigation. The Commission's staff will cooperate with the staff of the New York Public Service Commission in the conduct of this agency's investigation. The results of our staff's investigation will be shared fully with the President, the Congress and the consuming public.

By the Commission.

(S E A L)

Kenneth F. Plumb,
Secretary.

UNITED STATES OF AMERICA
FEDERAL POWER COMMISSION

Before Commissioners: Charles B. Curtis, Chairman;
Don S. Smith, and Georgiana Sheldon.

Investigation of Major Power Outages On Entire System of Consolidated Edison Co. of N. Y. July 13-14, 1977	)	Docket No. E-9599

SUPPLEMENTAL ORDER INSTITUTING FORMAL INVESTIGATION

(Issued August 12, 1977)

In response to a Presidential directive of July 14, 1977, the Commission initiated an investigation of the blackout which occurred in the Consolidated Edison Company service area on July 13-14, 1977. A preliminary Staff report relating to the blackout was issued on August 4, 1977, concluding the first phase of the Commission's investigation.

The results of the preliminary report have raised questions which can only be resolved after a thorough examination of the Consolidated Edison electric system and the companies with which it is interconnected. Pursuant to the authority vested in this Commission by the Federal Power Act the Commission authorizes and directs the Commission Staff to continue its investigation of the power failure on the Consolidated Edison electric system and to issue a final report.

Accordingly, we hereby extend by this order our previous direction to Consolidated Edison, the companies interconnected with its system and all New York Power Pool personnel, to cooperate fully with the Commission

DC-A-13

Staff in its continuing investigation. The Commission Staff will endeavor to cooperate with the staff of any duly constituted governmental body in the conduct of this investigation. As in the case of the preliminary Staff report, the final report will be shared fully with the President, the Congress, and the consuming public.

By the Commission.

(S E A L)

Kenneth F. Plumb,
Secretary.

Appendix B

FERC STAFF PARTICIPANTS

The Federal Power Commission's investigation was under the administrative direction of Jack L. Weiss, Acting Chief, Bureau of Power, until his retirement on September 3, 1977. The investigation and report were completed under the administrative direction of William W. Lindsay, Director, Office of Electric Power Regulation. Principal technical investigators were—

Edward J. Fowlkes
Chief
Reliability Analysis Branch
Walter J. Gundersen
Electrical Engineer
James K. Newton
Electrical Engineer
Martin J. Thorpe
General Engineer
Raymond K. Buffett
Chief
Electric Resources and Requirements Branch
Atlanta Regional Office
Johnny R. Johnson
Electrical Engineer
Fort Worth Regional Office
William E. Scott
Electrical Engineer
Fort Worth Regional Office

Other Federal Energy Regulatory Commission (formerly Federal Power Commission) staff members participating in the investigation included—

Office of Electric Power Regulation (formerly Bureau of Power)

Bernard B. Chew
Houshang Emami
Erastace N. Fields
Clifford M. Lane, Jr.
Daniel G. Lewis
Frank C. Miller
Lawrence A. Wilson

Office of the General Counsel

Daniel Goldstein
Charles F. Reusch
Robert F. Shapiro

Atlanta Regional Office

John W. Snellgrove, Jr.

New York Regional Office

Jonas Barish
Gilbert J. Cigal
Vincent Hom
John E. Pazmino

The Federal Energy Regulatory Commission engaged Dr. Joseph G. Colmen, of Education and Public Affairs, Inc., to make a special study of Con Edison's selection and training program for system operators. Dr. Colmen's report is given in appendix E.

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Appendix C

THE FUNCTIONS OF THE NEW YORK POWER POOL, THE NORTHEAST POWER COORDINATING COUNCIL, AND THE NORTH AMERICAN POWER SYSTEMS INTERCONNECTION COMMITTEE

THE NEW YORK POWER POOL

The purpose of the New York Power Pool (NYPP), as stated in the NYPP agreement, is to obtain the substantial mutual benefits for all members by "coordinated operation of their electric systems, including increased reliability of service and reduced capital costs made possible by coordinated system planning and reduced operating costs made possible by the interchange of electric energy for economy purposes." The agreement establishes the Power Pool Control Center "for the principal purposes of (1) coordinating the operations of the member companies of the Power Pool insofar as they may affect the reliability of the bulk power supply on the interconnected systems in New York State; (2) dispatching energy requirements on an economy basis; and (3) monitoring the internal and external operations of the Power Pool to insure unimpaired overall security of bulk power supply at all times."

The initial NYPP agreement was signed on July 21, 1966. The NYPP, as then established, replaced separate pooling arrangements between groups of upstate and downstate companies that had been in effect for some time. A later agreement dated March 31, 1971, was entered into by the seven original investor-owned utilities, with the addition of the Power Authority of the State of New York. The membership now includes the following organizations:

(1) Central Hudson Gas & Electric Corp.
(2) Consolidated Edison Co. of New York, Inc.
(3) Long Island Lighting Co.
(4) New York State Electric & Gas Corp.
(5) Niagara Mohawk Power Corp.
(6) Orange & Rockland Utilities, Inc.
(7) Rochester Gas & Electric Corp.
(8) Power Authority of the State of New York

The reasons for the later agreement were principally to strengthen the organization and to establish, staff, and operate a power pool control center facility located near Albany, New York. The agreement was further modified, and the present agreement, which became effective April 27, 1975, is on file with the Federal Energy Regulatory Commission (FERC) as a rate schedule of each investor-owned company.

The executive committee reviews and directs the activities of the five other committees of the pool and determines policy on all matters within the agreement and the carrying out of its provisions.

The functions of the five committees directing the staff of the pool are briefly described as follows:

(1) The operating committee establishes rules and practices required to coordinate the operation of the bulk power supply system of the pool's members so as to insure service reliability and economic operation with due regard for environmental factors.

(2) The planning committee has the responsibility for coordinating and developing plans for the installation of additional generating capacity and interconnecting transmission lines within the pool. The committee is also responsible for the coordination of planning between the pool and adjoining pools and regional reliability coordinating councils to the extent appropriate.

(3) The three remaining committees, dealing with energy management, environment, and public relations, support the primary functions of operating and planning the NYPP.

In 1976 Con Edison contributed approximately 39 percent of the pool's annual peak hourly demand, which occurs in the summer. Con Edison's system energy requirements were about 32 percent of those of the entire pool. Also, Con Edison's peak hourly demands were 61 percent larger than Niagara Mohawk Power Corp., the next largest system. However, Con Edison supplied the smallest geographic service area of all the members of the NYPP. Table C-1 shows the size relationship of Con Edison to NYPP in 1976.

Table C-1.–*Con Edison Size Relationship to NYPP, 1976*

Quantity	NYPP	Con Edison
Peak hourly demand (MW)	19,262	7,579
Energy requirements (MkWh)	112,000	35,818
Owned generation (MW)	29,699	9,880

Since the 1965 Northeast blackout, there have been no power interruptions resulting in a complete system collapse until the recent blackout on Con Edison's system. However, there have been a number of power interruptions and load reductions reported to the FPC since 1965.

Pursuant to FPC Order No. 331-1 in Docket R-361, utilities are required to report interruptions of bulk electric power supply caused by the outage of any generating unit or electric facility operating at a nominal voltage of 69 kV or higher and resulting in a load loss for 15 minutes or longer of at least 100 MW, or for smaller systems, one-half or more of the annual peak load. Also, load reductions effected by appeals to the public for curtailment of use, load reductions due to system voltage reductions, and any unusual hazard to the bulk power supply system are required to be reported. Reports that are made by telephone or telegraph during extended interruptions are followed by written reports.

The NYPP agreement establishes the coordination procedures for members within the pool. The structure of the pool with respect to committees has been noted. The obligations of member systems under the NYPP agreement are summarized in part as follows:

(1) *System planning*—each member is to furnish the planning committee system load and capability forecasts, statistical data, and any other information that may reasonably be required in the course of the studies undertaken by the committee.

(2) *Installed capability reserve*—each member is required to maintain 18 percent system capability over its maximum peak hour load for a capability period (summer or winter). A system of charges and payments between individual members and the pool is used to account for variances from the 18 percent requirement.

(3) *Operating capability*—each member agrees to provide the required minimum operating reserve as established by the operating committee. The operating reserve must be acquired from owned resources or through purchases.

The agreement sets conditions for economy energy purchases among the parties as well. In April 1977, the NYPP instituted centralized economic dispatch for all the member systems.

Examples of other activities or studies requiring intrapool coordination performed in 1976 by the NYPP, as reported by the Northeast Power Coordinating Council (NPCC) under FPC Order No. 383-4, are the following:

(1) *1980-to-1982 study of the NYPP system voltage and voltage control*—this study evaluates the capability of the proposed 1980-to-1982 system to adequately control voltage on the 115-kV through 765-kV systems and recommends additional means of control, if required.

(2) *1980, 1985, and 1990 NYPP transmission studies*—these studies assess the performance of the NYPP internal transmission systems as proposed by the member companies. In addition, numerous alternative reinforcements were considered for each of the three years.

(3) *1982, 1987, and 1993 NYPP transmission studies*—these three transmission studies are follow-on studies from the 1980, 1985, and 1990 series, wherein the proposed system performances were assessed. The alternative reinforcements found best in the 1980, 1985, and 1990 studies were reviewed in these studies.

Another major activity of the pool is the preparation of the NYPP annual report to the New York Public Service Commission on the electric power requirements, long-range generation and transmission expansion plans, and projected research and development activities of the pool members. This reporting requirement is pursuant to article VIII, section 149-b, of the Public Service Law of New York.

Interpool coordination on matters of exchanging information on transmission and generation overhaul and maintenance schedules, near-term capacity situations, and other operating matters is handled within the NPCC's Task Force on Interpool Coordination. Members of this task force include not only representatives from the New England Power Pool (NEPOOL), Ontario, and New Brunswick (all within NPCC), but also from the Michigan Electric Coordinated Systems (MECS) and the Pennsylvania-New Jersey-Maryland Interconnection (PJM). The NPCC task force on interpool coordination also reviews system disturbances and provides liaison with the North American Power Systems Interconnection Committee (NAPSIC). NAPSIC is the voluntary operating organization in which virtually all interconnected power systems in the United States and parts of Canada have membership.

NYPP is interconnected directly with the systems of NEPOOL, PJM, and Ontario. The interconnection agreements between members of the NYPP and of neighboring pools or systems are on file with FERC.

Figure C-1 provides the geographic location and type of interstate transmission tielines of the NYPP systems.

The latest interconnection agreement between th seven investor-owned utilities within NYPP and th

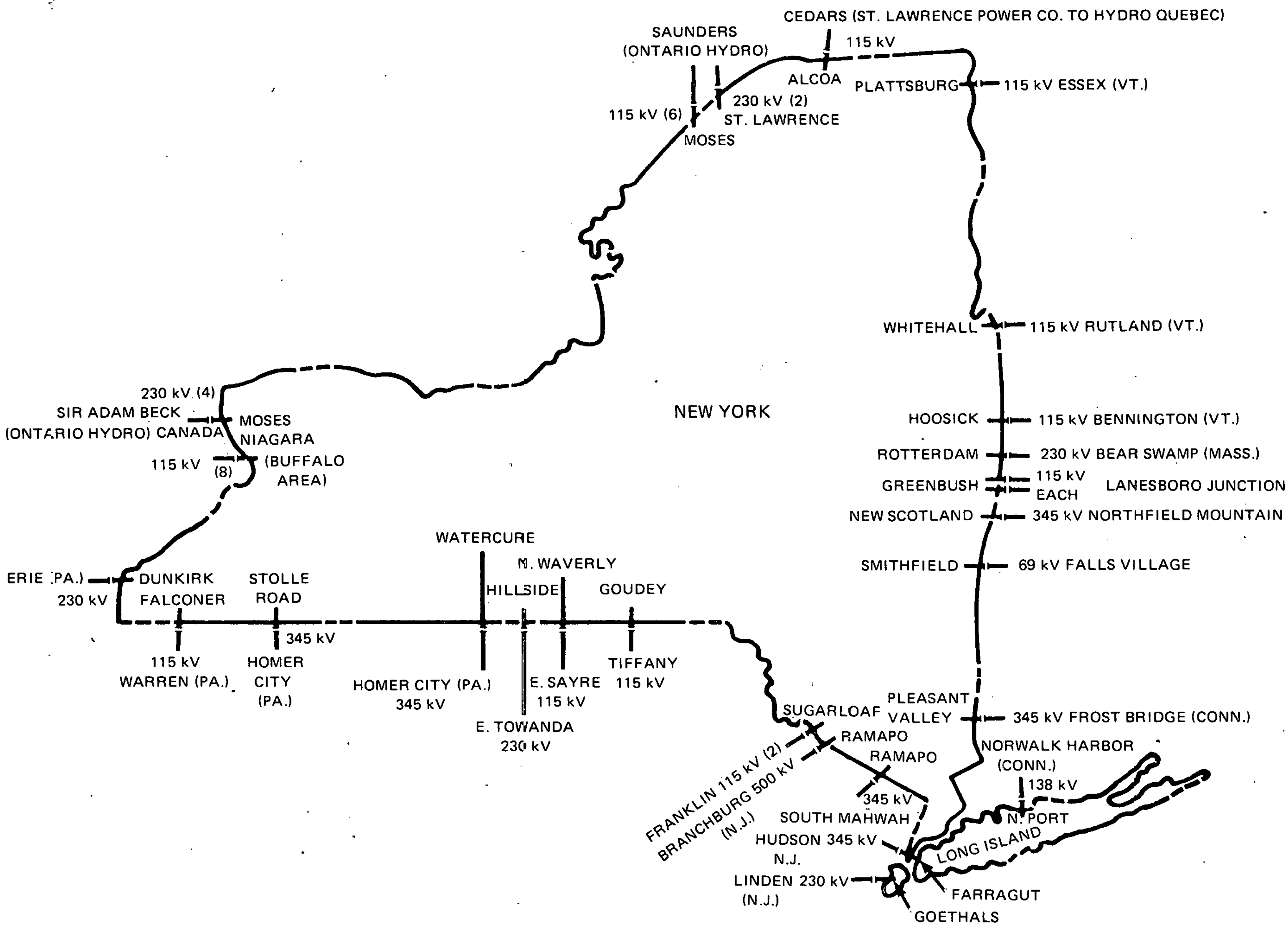

Figure C-1.–Electric power system interconnections, State of New York, July 1977.

eight members of PJM[1] became effective August 1, 1974. This agreement provides for continued parallel operation of the two areas and calls for both areas to "cooperate in the exchange of information with regard to pertinent matters affecting the planned development and reliable operation of their respective systems, shall cooperate in the determination of the benefits of interconnection and of their installed capacity requirements, and, to the extent possible, shall coordinate generating capacity and major transmission additions required" by the two areas. Either NYPP or the PJM parties "in the event of breakdown of equipment, unusual load demands, or unusual or abnormal conditions in the other Group's system resulting in the need for capacity or energy in excess of that available from sources within or available to that Group, shall, if called upon, supply Emergency Operating Capacity, Emergency Energy or Non-Replacement Energy to the other Group."

The agreement provides for an NYPP/PJM operating committee staffed by respective area personnel to carry out the terms of the agreement.

THE NORTHEAST POWER COORDINATING COUNCIL

On January 19, 1966, very shortly after the Northeast blackout, executives representing electric systems in New York, New England, and Ontario signed a memorandum of agreement establishing NPCC, the first organization of its kind in North America.

The following year, the FPC's Industry Advisory Committee on Reliability of Bulk Power Supply singled out regional coordination as "the most effective and economical means for assuring bulk power supply reliability for the Nation."[2] Concurring with this view, FPC recommended that "strong regional organizations need to be established throughout the Nation for coordinating the planning, construction, operation, and maintenance of bulk power supply." By the end of 1967, utilities had voluntarily established five coordinating councils to improve power supply reliability within their respective regions. Presently, there are nine regional electric reliability councils, which cover virtually all interconnected systems in the continental United States and bordering provinces of Canada (fig. C-2).

NPCC now consists of 21 member systems that supply about 98 percent of the electric requirements in New England, New York, and the Canadian provinces of Ontario and New Brunswick.

The purpose of NPCC as stated in its memorandum of agreement "will be to promote maximum reliability and efficiency of electric service in the interconnected systems of the signatory parties by extending the coordination of their planning and operating procedures." Full membership is limited to electric utility systems, whether investor-owned companies or governmental agencies, which, by virtue of generating or transmission capacity or concentration of load, can have a substantial effect on the service reliability of the interconnected systems.

The work of the council is done by an executive committee, three standing committees on system design, operating procedures, and public information, and nine task forces, which carry on studies of all important aspects of bulk power supply reliability. In addition, the council has a technical staff of full-time employees. The list of NPCC members follows:

Member systems	*Executive offices*
Boston Edison Co.	Boston, Mass.
Burlington Electric Department	Burlington, Vt.
Central Hudson Gas & Electric Corp.	Poughkeepsie, N.Y.
Central Maine Power Co.	Augusta, Maine
Central Vermont Public Service Corp.	Rutland, Vt.
Consolidated Edison Co. of New York	New York, N.Y.
Eastern Utilities Associates	Boston, Mass.
Northeast Utilities	Hartford, Conn.
Ontario Hydroelectric Power Commission	Toronto, Ontario, Canada
Orange & Rockland Utilities, Inc.	Spring Valley, N.Y.
Power Authority of the State of New York	New York, N.Y.
Public Service Co. of New Hampshire	Manchester, N.H.
Rochester Gas & Electric Corp.	Rochester, N.Y.
The United Illuminating Co.	New Haven, Conn.
Green Mountain Power Corp.	Burlington, Vt.
Long Island Lighting Co.	Mineola, N.Y.
The New Brunswick Electric Power Commission	Fredericton, New Brunswick, Canada
New England Electric System	Westboro, Mass.
New England Gas & Electric Assoc.	Cambridge, Mass.
New York State Electric & Gas Corp.	Binghamton, N.Y.
Niagara Mohawk Power Corp.	Syracuse, N.Y.

[1]The eight members of PJM are the following: Public Service Electric & Gas Co.; Philadelphia Electric Co.; Pennsylvania Power & Light Co.; Baltimore Gas & Electric Co.; Potomac Electric Power Co.; Pennsylvania Electric Co.; Metropolitan Edison Co.; and Jersey Central Power & Light Co.

[2]Federal Power Commission, *Prevention of Power Failures; Volume II—Advisory Committee Report: Reliability of Electric Bulk Power Supply,* June 1967. Power Supply, June 1967.

Figure C-2.–Northeast Power Coordinating Council, member regions.

Four distinct planning and operating entities exist within the NPCC region, two in the United States and two in Canada. NPCC member systems located in New England are also members of NEPOOL, and systems in New York State are members of the NYPP—both of which operate under formal agreements on file with FERC. New Brunswick Electric Power Commission and Ontario Hydro are single entities serving their respective provinces in Canada.

NPCC's "Memorandum of Agreement," discussed earlier, and its "Statement of Principles Regarding the Council's Role in Planning," approved July 8, 1970, form the basis for the overall work of the committees, task forces, working groups, and technical staff. The "Statement of Principles" lists the following:

(1) The system members of NPCC are to report periodically their 10-year plans (including alternatives) for transmission and generation.

(2) NPCC is to evaluate the plans from the standpoint of suitability for and the reliability of the Northeast Interconnected Systems and report its assessment and recommendations to the membership.

All members of NYPP are members of NPCC. NYPP is one of the four areas of NPCC that provide a focus for electric system planning and operation. All members of the NYPP are bound by the multiparty pool agreement filed with FERC. The agreement not only provides the means whereby the member systems can coordinate system planning and operations (a similar function of the NPCC), but also establishes rates and charges for equitable sharing in the benefits of such coordinated actions. The agreement also establishes the NYPP Control Center, which coordinates the operations of NYPP, dispatches energy requirements on an economic basis, and monitors security of the systems. The control center can then sell or purchase electric power and energy not only from the other three area dispatch centers (NEPOOL, Ontario, New Brunswick) within NPCC, but also from dispatch centers of other adjacent systems.

NPCC reviews the generation and transmission expansion plans for all four areas within NPCC. The test for each area plan, including the NYPP, is wheth it meets the established NPCC "Basic Criteria for t Design and Operation of Interconnected Power Systems."

All of the present nine regional reliability councils, including NPCC, belong to the National Electric Reliability Council (NERC), which was formed in June 1968 to encourage improvement of coordination at both the regional and national levels. (See fig. C-3.) Its stated purposes are—

(1) To encourage and assist the development of interregional reliability arrangements among regional organizations for their members

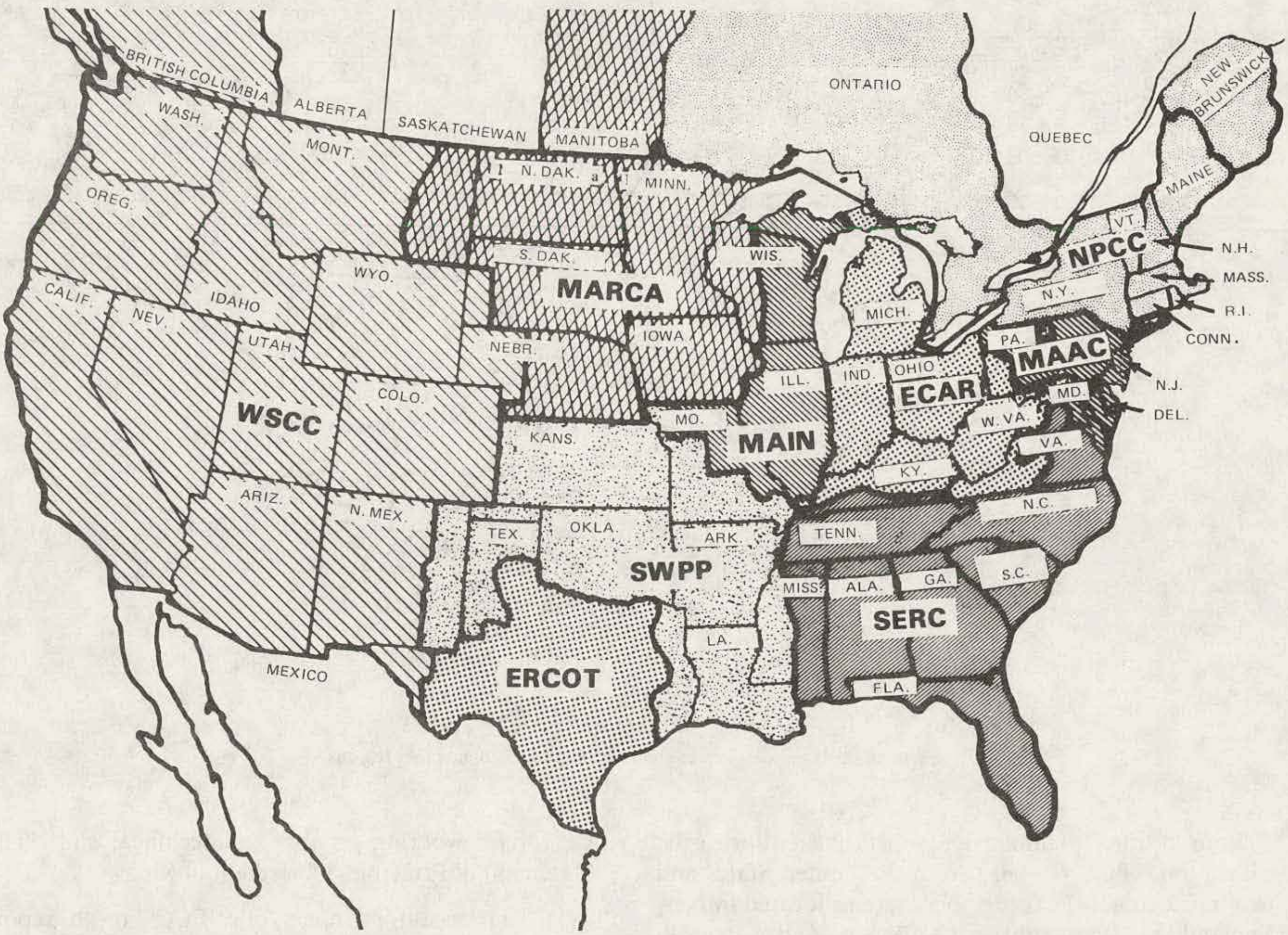

Figure C-3.–Regional electric reliability councils, regions, October 1975.

(2) To exchange information on planning and operation matters relating to the reliability of bulk power supply

(3) To review, periodically, regional and interregional activities on reliability

(4) To provide independent reviews of interregional matters referred to it by a regional organization

(5) To providc information to FERC and other Federal agencies

NPCC is represented on all major NERC standing committees. In addition, NPCC regularly acts as a vehicle for providing information requested by NERC and for disseminating NERC reports to the member systems.

Besides NPCC's membership in NERC, NPCC maintains two interstate coordination agreements between the executive boards constituted under the Mid-Atlantic Area Council (MAAC) and the East Central Area Reliability Coordination Agreement (ECAR)—both being other reliability councils. Each of these agreements establishes an interarea review committee the purposes of which are—

(1) To exchange information on respective activities and decisions, including system future plans and forecasts

(2) To examine the effects of activities and decisions in one area on the reliability of bulk power supply in the other area and report findings to the respective parties

NPCC has entered into joint interarea studies with both ECAR and MAAC. Under the direction of a joint interarea review committee, the MAAC/ECAR/NPCC (MEN) study committee directs two working groups:

(1) The MEN Future Systems Working Group studies interregional transmission electric power transfer capabilities.

(2) The MEN Operating Studies Working Group performs power transfer capability and limited reliability assessments during the time of summer and winter peaks for each year. For example, the "1977 Summer Operating Study" was completed in May 1977 and includes—

(a) Appraisal of normal operating conditions

(b) Summary of 1977 summer emergency transfer capabilities

(c) Appraisal of network stability

THE NORTH AMERICAN POWER SYSTEMS INTERCONNECTION COMMITTEE

NPCC participates by way of its members in NAPSIC. In 1962, representatives of interconnected systems throughout the United States and parts of Canada met and laid the groundwork for a voluntary international organization for coordinating the operation of a developing coast-to-coast interconnected network. This led to the formation of NAPSIC. Currently, there are ten NAPSIC operating areas within three major interconnected systems in the United States and Canada: the Eastern Interconnected System, the Western Interconnected System, and the Texas Interconnected System. NPCC comprises about 18 percent of the total peak demand in the Eastern Interconnected System (EIS), and EIS represents about 75 percent of the total peak demand for the entire United States and eastern Canadian interconnected systems.

The principal goals NAPSIC set for itself were coordination of frequency, establishment of operating criteria related to time error, and establishment of tieline bias settings. NAPSIC publishes an operating manual that includes twenty-two operating guides that include emergency operating procedures. Although the guides establish general principles and operating criteria for coordinated operation, they are not explicit enough to be used as detailed specifications for system operation.

NAPSIC's contribution to reliable system performance is enhanced by its close liaison with planning entities, regional reliability councils, and NERC.

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Appendix D

TRANSCRIPTS OF TAPED TELEPHONE CONVERSATIONS, JULY 13, 1977

This appendix contains transcripts of taped telephone conversations on the evening of July 13, 1977, of the following:

(1) New York Power Pool (NYPP) senior pool dispatcher
(2) NYPP pool dispatcher
(3) Con Edison system operator
(4) Con Edison power dispatcher

Each transcript shows the times at which the conversations took place. The transcripts are complete except for the deletion of expletives.

A glossary of the abbreviations used to identify the participants is included preceding the transcript texts.

GLOSSARY

AK 2	Con Edison, Arthur Kill No. 2, operator
AST GTs	Con Edison, Astoria Gas Turbine Site
CE PD	Con Edison, power dispatcher
CE SO	Con Edison, system operator
CH LD	Central Hudson Gas & Electric Corp., load dispatcher
CSO	Con Edison, chief system operator
ECC	Energy control center (background)
ER	Con Edison, East River, operator
ER 5	Con Edison, East River No. 5, operator
GEN STA	Con Edison, any of several generating stations, otherwise unidentified
HA	Con Edison, Hudson Avenue, high board operator
LI DO	Long Island Lighting Co., district operator
LI SO	Long Island Lighting Co., system operator
MDO	Con Edison, Manhattan district operator
Narrows	Con Edison, Narrows gas turbine site
NEC	New England Power Exchange, pool coordinator
NM PD	Niagara Mohawk Power Corp., power dispatcher
NM SS	Niagara Mohawk Power Corp., shift supervisor
NM APD	Niagara Mohawk Power Corp., assistant power dispatcher
NYPP APD	New York Power Pool, assistant pool dispatcher
NYPP PD	New York Power Pool, pool dispatcher
NYPP SPD	New York Power Pool, senior pool dispatcher
NYSEG SD	New York State Electric & Gas Corp., system dispatcher
O&R SO	Orange & Rockland Utilities, Inc., system operator
OH PS	Ontario Hydro, production supervisor
OH SO	Ontario Hydro, system operator
PASNY LD	Power Authority of the State of New York, load dispatcher

PASNY SS	Power Authority of the State of New York, system shift supervisor
PGO	Con Edison, power generation operations
PJM AID	Pennsylvania-New Jersey-Maryland Interconnection, assistant interconnection dispatcher
PJM ID	Pennsylvania-New Jersey-Maryland Interconnection, interconnection dispatcher
PSE&G	Public Service Electric & Gas Corp.
QDO	Con Edison, Brooklyn & Queens, district operator
RAV 2	Con Edison, Ravenswood Nos. 1 & 2, operator
RAV 3	Con Edison, Ravenswood No. 3, operator
RGE LD	Rochester Gas & Electric Corp., electric load dispatcher
SIDO	Con Edison, Staten Island, district operator
WAT	Con Edison, Waterside, high board
WDO	Con Edison, Westchester, district operator
WES	Con Edison, Westchester, emergency supervisor
59TH ST	Con Edison, 59th Street, high board
74TH ST	Con Edison, 74th Street, high board

TRANSCRIPT OF JULY 13, 1977, TELEPHONE TAPE OF NYPP SENIOR POOL DISPATCHER

Time	*Company and position*	*Conversation*
20:37:21	NYPP APD	Indian Point 3, huh?
	NYPP SPD	Looks like it.
	PASNY SS	Looks like we have problems at Indian Point.
	NYPP SPD	Looks like she's down, period.
	PASNY SS	Yeah, it's pretty . . . close to it—there she goes. It's off.
	NYPP SPD	Yep. OK, fine.
20:38:04	NYPP PD	Yeah, Jim.
	PJM ID	What are you doing?
	NYPP PD	I lost Indian Point 3.
	PJM ID	Indian Point 3?
	NYPP PD	Yeah—900 on it.
	PJM ID	OK.
	NYPP PD	Okey, dokey.
20:40:53	NYPP SPD	Yes, sir.
	CE PD	Can you give us a hand at getting 81 deloaded?
	NYPP SPD	Yeah, we were just looking at it there. We are going to cut some of that New England stuff off there—that really should relieve some of it, OK?
	CE PD	Unhuh.
	NYPP SPD	OK.
	CE PD	Alright, Willie.
	NYPP SPD	Fine and dandy.
20:41:23	NYPP SPD	Hello.
	PASNY SS	We are going to have to change our schedule all around for that 21:00 or 22:00 hour.
	NYPP SPD	The 22:00 hour?
	PASNY SS	Yeah, we are going to have to get rid of the transfer—we got to get support for Fitz—and, we have to support as much of the preferred customer load as we can.

Time	Company and position	Conversation
	NYPP SPD	Well, I don't know how you are going to handle it—it's too late to change anything now, John.
	PASNY SS	Bill, I got to do it.
	NYPP SPD	Well—.
	PASNY SS	This . . . stuff is too expensive—and if I support it, I got to support it.
	NYPP SPD	Well, I don't know, that's between you and Con Edison. You'd better talk to him because—
	PASNY SS	I got to get rid of my transfer to Hydro.
	NYPP SPD	Yeah, well you talk to Con Edison because that transfer is between the two of you, so—
	PASNY SS	I know it, but I got to support as much of it as I can.
	NYPP SPD	Yeah, well, we can't do nothing now—we're cutting emergency from the outside world, that's all we're doing trying to get underneath this thing.
	PASNY SS	Alright.
	NYPP SPD	OK.
20:42:22	NYPP SPD	Hello.
	CE SO	Yeah, on that 81—I need at least 100 MW off it.
	NYPP SPD	OK. We're cutting emergency from New England there Bill, so it should be coming back there.
	CE SO	OK. Are you doing it right away?
	NYPP SPD	Yep, we already cut it, so it should be coming back there.
	CE SO	OK. Because I'm over there—the normal is 825, I'm going to 974.
	NYPP SPD	Yeah—OK—you're still below the long time. We've cut the emergency so you should be getting some relief on it.
	CE SO	OK. Thank you.
	NYPP SPD	You bet.
20:43:45	LI SO	Yeah, Ken.
	NYPP SPD	Hello, Kenney. Can you pick anything up down there?
	LI SO	Yeah, a little.
	NYPP SPD	OK. Pick up what you can do.
	LI SO	Yeah. You guys in trouble, or what?
	NYPP SPD	Yeah, it's Indian Point 3 there.
	LI SO	Oh, OK.
20:43:57	NYPP SPD	Kennedy.
	NEC	Yeah, Bill, is he sure he wants them to cut that out?
	NYPP SPD	Yeah, we got to cut it, we're overloaded on the 81 line.
	NEC	Very good.
	NYPP SPD	OK. Thank you.
20:45:22	CE SO	Yeah, Bill.
	NYPP SPD	You getting your turbines on Willie?
	CE SO	Yes.
	NYPP SPD	OK, fine. That 81 is beginning to come down there now a little bit.
	CE SO	Yeah, I see it now.

Time	Company and position	Conversation
	NYPP SPD	OK, fine.
20:48:50	NM SS	System, Kuhl.
	NYPP SPD	Yeah, Donald. They having trouble getting those jets started are they, or what?
	NM SS	I don't know—they're coming.
	NYPP SPD	Yeah.
	NM SS	And, so is Christmas.
	NYPP SPD	Well, we're dragging pretty near. Let's see, looks about 800 here right about now.
	NM SS	Indian Point 3, huh?
	NYPP SPD	Yeah. I didn't get any official time—looked like 20:37, but I asked for reserve pickup with this stupid thing, but it isn't doing me much good.
	NM SS	Yeah. You know, we lost a couple of minutes there though, Bill. I think if he would have just jingled emergency just to call everyone's attention to look—I didn't even really see it for a minute or two here. Finally a guy from Albany called us and said, "Hey, what happened?" Then I quick looked at the charts and there it was.
	NYPP SPD	Yeah, maybe we should have went out on the hotline, but—
	NM SS	Of course, you are supposed to follow your DNI. I know, but even then I waited until the first one came in to see whatever it called for.
	NYPP SPD	Yeah. It's probably a good practice to get into, going out on the hotline telling them that we did lose something—to follow the base points, but I really wasn't too anxious to get yours up too much because we have an overload down on the Con Edison line anyway, until I cut some emergency off coming from New England. So, I'm still over the normal limit, but I still got room for 70 or 80 to pick up going down there.
	NM SS	Look like we're going to be in it the next hour or two?
	NYPP SPD	Well, I don't know. He's ordered his gas turbines on. If he gets the . . . stuff up there, I don't know. It will probably be a while. Then PASNY wanted to change the schedule right in the middle of all this. Hey, I can't accept no schedule changes right now. I said that's strictly between you and Con Edison. He wanted to support—pick up the support or something. I don't know what the . . . he wanted. You don't have time to fool with that stuff. Better begin to recover a little bit here, little by little, but I think he lost more than Indian Point 3 by the looks of me—looks like he lost that whole Buchanan South bus down there. The same thing happened before, but—OK, fine.

Time	*Company and position*	*Conversation*
	NM SS	OK.
20:53:29	NYPP SPD	Kennedy.
	OH SO	Bill, you lose a big one somewhere?
	NYPP SPD	Yeah, Indian Point 3.
	OH SO	Oh, there it is. Is that the nuclear unit?
	NYPP SPD	Yeah, it's a nukie, yeah.
	OH SO	Number 3 with a thousand megs on it?
	NYPP SPD	Yeah, just about.
	OH SO	Did they go out on a straight line or did they—?
	NYPP SPD	All I see is a straight line. I don't know, I haven't heard anything from the company down there yet, and I'm trying to get this generation up to cover the . . . thing. We're still dragging about 500 here, but I can't pick it up north or wherever generation is—too fast, on account I'll overload his system.
	OH SO	Yeah, we can't help you either because our interface is right up.
	NYPP SPD	Yeah, the tie is right up there. Yeah, we're probably dragging you up too.
	OH SO	Yeah, a little bit. Yeah, but you can't help that.
	NYPP SPD	Yeah, well, we're trying to get under it.
	OH SO	Who owns Indian Point, PASNY?
	NYPP SPD	PASNY owns it, but it's down Con Ed system, down in New York.
	OH SO	Oh, OK. I'll let you go.
	NYPP SPD	Alright, fine, thank you.
20:56:07	CE SO	Yeah.
	NYPP SPD	Bill, you'd better get that Linden back or you'll lose that baby, too.
	CE SO	Yeah, I just lost 81.
	NYPP SPD	You lost the Jamaica tie, too.
	CE SO	Huh?
	NYPP SPD	You lost the Jamaica tie, too.
	CE SO	Which Jamaica tie?
	NYPP SPD	The Jamaica Valley Stream.
	CE SO	Oh, that could be. Alright, but help me out with the 81/80 feeder, huh. Yeah.
20:56:54	NYPP SPD	Bill, you better shed some load until you get down below this thing because I can't pick anything up except from the north, see?
	CE SO	Yeah.
	NYPP SPD	So, you'd better do something to get rid of that until you get yourself straightened out.
	CE SO	I'm trying, I'm trying.
	NYPP SPD	OK, fine.
20:57:12	NYPP PD	Yeah.
	NM PD	Pete, now they want to take the . . . 37 out of there that they were transferring in the first place.
	NYPP SPD	Hey, look. Tell them we have major problems; we ain't got time to fool around with this stuff. They just lost the Jamaica Valley Stream, the 81 feeder down there. Con Ed is in dire emergency down there.

Time	*Company and position*	*Conversation*
	NM PD	OK, that's what I'm trying, but they said that Con Ed said they couldn't take the . . . 37.
20:58:38	NYPP SPD	Yeah, I know that Linden's up there. I already told them to try to get it down. He's got a major emergency over there and he's lost the 81 line, and he's lost the Jamaica Valley Stream.
	PJM ID	OK.
	NYPP SPD	I told him he'd better shed some load down there.
	PJM ID	Yeah, PS is going to open that Linden/Goethals if they don't do something about it.
	NYPP SPD	Yeah, I told him he's going to have to get that thing down somehow or other.
	PJM ID	OK, fine.
20:59:15	CE SO	Yeah, Bill.
	NYPP SPD	Bill, I hate to bother you, but you'd better shed about 400 MW of load or you're going to lose everything down there.
	CE SO	Bill, I'm trying to.
	NYPP SPD	You're trying, all you got to do is hit the button there and shed it and then you worry about it afterwards, but you got to do something or they're going to open up that Linden tie on you.
	CE SO	Yeah, right. Yeah, fine.
21:00:45	Mrs. LeBlanc	Hello.
	NYPP SPD	Is Don LeBlanc around, please?
	Mrs. LeBlanc	Yep, just a minute, please.
	D. LeBlanc	Yes, sir.
	NYPP SPD	Don, we have a major emergency here—if you want to come down.
	D. LeBlanc	OK, I'll be right down, Bill.
21:01:41	NYPP SPD	Kennedy.
	PJM ID	Hey, Mr. Kennedy.
	NYPP SPD	Yes, sir.
	PJM ID	Do you have anything to help that Linden/Goethals?
	NYPP SPD	No, I told them to shed load down there, and he hasn't done it yet. I told him that you were going to open the tie if he didn't get it back. He did get it back some there, but he's overloaded on his—you see he's lost the 80 line—he's overloaded on the 81 line. He's 500 over the short-time emergency right now. I told him to shed 400 load but he hasn't done it.
	PJM ID	Where's this at?
	NYPP SPD	The Millwood area.
	PJM ID	The Millwood?
	NYPP SPD	Yeah. So, we're trying—the best we can do—if you can hang in there. I know we're pulling pretty heavy on that tie. I don't want to lose it any worse than you do—we've lost two or three ties already.
	PJM ID	You have?
	NYPP SPD	Yeah.

Time	*Company and position*	*Conversation*
	PJM ID	Keep our fingers crossed.
	NYPP SPD	OK. There, he's calling me now.
21:02:22	NYPP SPD	Hello.
	CE SO	Look any better?
	NYPP SPD	No. You still got to get rid of about 400, Bill, because you're 400 over the short-time emergency on that 80 line.
	CE SO	Yeah, that's what I'm saying. Can you help me out with that?
	NYPP SPD	I can't do nothing because it's got to come from the lower part of the State, and there's nothing there to help you with. You got to do it in—
	CE SO	There's no GT to put on because they went home.
	NYPP SPD	OK, then you're going to have to shed load because that's the only way that thing is going to save you til you get them . . . things on because I told Long Island to pick up everything he had, and that's the only place that I can get into you.
	CE SO	Can you help me?
	NYPP SPD	There's no way I can help you, see? OK, Will?
21:03:01	NYPP SPD	Hello, hello.
	PJM ID	He's not moving anything.
	NYPP SPD	Yeah, he's working at it, just hang in there, Dick. I just talked to him again, and told him to shed 400 MW of load there.
	PJM ID	OK.
	NYPP SPD	He's got it down some there, he's got it backed down there some because—
	PJM ID	He's got 731 showing up.
	NYPP SPD	Yeah, I know—she's up there. He's lost two or three other ties there. OK?
	PJM ID	OK. I see it.
21:04:36	LI SO	Yeah.
	NYPP SPD	You starting everything you got to go down there?
	LI SO	Yeah.
	NYPP SPD	OK. Put her on there whatever you got to go.
	LI SO	What happened with Con Ed?
	NYPP SPD	Well, he's lost a couple of other ties, besides Indian Point 3, so we got to get—.
	LI SO	We can't pull anymore in on that tie, can we?
	NYPP SPD	No. Len, push it out. Pick up everything you got and push it out. Push your load into Con Edison.
	LI SO	I got the CLP overloaded, though.
	NYPP SPD	Yeah, OK, try to relieve that, but push everything you got to give to Con Edison; get all the generation out that you can get down there.
21:05:08	CE SO	Bill, I'm going to cut feeder 80; I've no way of deloading it right now.
	NYPP SPD	Can't you shed load and relieve it? If you cut feeder 80, then you are really going to be in trouble.

Time	*Company and position*	*Conversation*
	CE SO	I'll see what I can do.
	NYPP SPD	Alright.
21:05:35	NYPP SPD	Yeah, Willie.
	CE SO	Can't Roseton back off?
	NYPP SPD	I can have Roseton back off, but that's not going to help your 80 line because that's coming down through Ramapo. Going down in the bottom—
	CE SO	It's coming down from Roseton.
	NYPP SPD	Yeah, well I've asked all to back off up there but it's not going to help you, Bill.
	CE SO	It should be able to help me if he backs off on their Roseton machines.
	NYPP SPD	Yeah, but you got nothing to pick up. See what I'm saying? You need something in the south to ease it off, and there's nothing you can do but shed load down there. You can't get your turbines on.
	CE SO	It's just the idea. I was figuring on going ahead of the game and letting them go naturally. I'm getting the Narrows put on and the Astoria machines put on.
	NYPP SPD	Yeah. If you get them on, then I can back off stuff from the north, see?
	CE SO	Right.
	NYPP SPD	OK.
21:06:22	NM PD	Syracuse—
	NYPP SPD	Can you back off some generation up there? You know we're loaded on this . . . 80 line—I'll try to get it down. He's 400 over the short-time emergency, but, I don't know. We look pretty good in the pool, but just back off some if you can. I'm going to have him back that Roseton down some.
	NM PD	Alright. I can bring them turbines back down.
	NYPP SPD	Yeah.
	NM SS	Now you're in a short-time emergency.
	NYPP SPD	He's exceeding it by 400 MW. I asked him twice to shed load down there and he hasn't—three times and he hasn't did it.
	NM SS	I know.
	NYPP SPD	I don't know what the . . . else to do. You know?
	NM SS	Want us to back our turbines down or what?
	NYPP SPD	Yeah, you'd better back down some. Whatever you can do to help.
	NM SS	OK, fine.
21:09:01	CE PD	Yes, sir.
	NYPP SPD	Bill, tell Bill to go into voltage reduction immediately down there. Alright?
	CE PD	OK. Good enough.
21:10:18	LI DO	Tommy Hogan.
	NYPP SPD	Would you have them institute 5 percent voltage reduction down there to help out Con Edison, please?

Time	Company and position	Conversation
	LI DO	Do you want us to go with the 5 percent VC to help out Con Ed?
	NYPP SPD	That is correct.
	LI DO	You are?
	NYPP SPD	Kennedy, at the pool.
	LI DO	Alright, thank you, Mr. Kennedy.
21:10:26	NYPP SPD	Yeah, Kenny.
	LI SO	Do you want every GT on we got available?
	NYPP SPD	Every GT you got on and 5 percent voltage reduction. OK, Ken, thank you.
21:13:10	CH LD	Yeah.
	NYPP SPD	Would you back Roseton down couple hundred megawatts?
	CH LD	Yes, but—alright.
	NYPP SPD	Don't worry about the base points, Bobby. We're overgenerating 200 right now and we need relief on this 80 line.
	CH LD	Yeah, I know. Is the 80 line open?
	NYPP SPD	Eighty-one is open, but the 80 line is over the short-time emergency.
	CH LD	OK. The 81 is open?
	NYPP SPD	That is correct.
	CH LD	I'll back off 200 MW, pronto.
	NYPP SPD	OK, but don't lose her; just bring her down.
	CH LD	Alright. Goodbye.
21:17:54	NYPP SPD	OK.
	CE PD	Yes, sir, Willie.
	NYPP SPD	Did you institute voltage reduction?
	CE PD	Yes sir, man, 5 percent.
	NYPP SPD	Five percent, eh? We're not getting much relief on that . . . tie. I had Long Island go into 5 percent also to try to help you guys, and we got Roseton coming down. I don't know what else I can do for you. If you lose that 80 line you're really going to be out of business.
	CE PD	You're not kidding, man; you're not kidding.
	NYPP SPD	OK. Well, if it doesn't come down, maybe we'd better go to 8 percent then.
	CE PD	OK.
	NYPP SPD	OK, fine.
21:19:02	NYPP SPD	Now, what the . . . did he lose.
21:19:07	NYPP SPD	Hello, hello.
21:20:30	NYPP SPD	Can't even get him on the phone.
21:20:34	CE PD	Yes, Willie.
	NYPP SPD	You got to shed load immediately or you're going to go right down the pipe with everything—you've lost that 80 line there now.
	CE PD	He lost the 80 line?
	NYPP SPD	Yeah, you'd better shed load immediately.
	CE PD	Oh—
	NYPP SPD	At least 600 MW, anyway.
	CE PD	Yep, OK.
21:22:20	NYPP SPD	John, will you shed load down there immediately?
	CE PD	Yeah.

Time	Company and position	Conversation
	NYPP SPD	At least 1,000 MW or you're going to go right down the pipe.
	CE PD	Alright, pal.
21:24:00	NYPP SPD	Kennedy.
	OH SO	Bill.
	NYPP SPD	Yes.
	OH SO	What time do you make that Indian Point 3?
	NYPP SPD	Oh, I ain't got time to even talk about that right now. We're in major emergency here. Call me back later, please.
	OH SO	Right.
21:24:07	NYPP SPD	Kennedy.
	NM SS	Yeah, Bill. You probably know, 115 going to Con Ed is loaded right to the . . . too.
	NYPP SPD	Yeah, I know it. I just told him to shed 1,000 MW of load and he hasn't done a . . . thing down there. The 80 line is open.
	NM SS	He's going to lose his shirt in a minute.
	NYPP SPD	He's going to go right down the pipe if he doesn't do something pretty soon.
	NM SS	Right.
	NYPP SPD	OK, Donald?
	NM SS	OK.
21:27:08	CE PD	Yes, sir, Bill.
	NYPP SPD	OK, I'm going to tell you one more time. If you don't shed about 600 MW of load immediately—.
	CE PD	He's doing it as fast as he can, pal.
	NYPP SPD	All you got to do is punch a button to get rid of it.
	CE PD	That's what he is doing, right now.
	NYPP SPD	Shed 600 MW immediately or you'll lose that Linden and you're out of business. That's the only thing you have left, John.
	CE PD	I know that.
	NYPP SPD	OK, fine.
	CE PD	Right.
21:27:37	NYPP SPD	What the . . . is going on? I can't find out. Hello, there.
	PJM ID	Are you dropping load?
	NYPP SPD	I just talked to him again, and he is in the process of dropping load. I told him to drop 600 MW on that Linden tie.
	PJM ID	You've got to get that . . . thing down.
	NYPP SPD	Yeah, I know it. I told him, I said, you lose that and you're out of business. That's the only tie he's got hanging in there.
	PJM ID	OK.
	NYPP SPD	Because Branchburg isn't doing him any good; because he's all open from there up.
	PJM ID	Waldwick/Hillsdale is way over too.
	NYPP SPD	Yeah. Well, if he gets that Linden down, that will help that. That's the only tie he has with the

Time	Company and position	Conversation
		outside world right now—is that Linden tie. If he loses that, he is out of business.
	PJM ID	Tell him to get it down because that's ah.
	NYPP SPD	I told him, Dick.
	PJM ID	Ain't much I can do for him.
	NYPP SPD	I know. I appreciate what you're saying, and I told him, I don't know how many times, but there's nothing else I can do. I don't have any buttons to push here.
	PJM ID	Alright.
21:28:31	NYPP SPD	Kennedy. Hello.
21:30:28	NYPP SPD	Back off some generation. It looks like he separated. We're pretty high here on the frequency.
	NM SS	OK. We'll drop a turbine.
	NYPP SPD	Alright, fine.
21:31:32	NYPP SPD	Hello.
	LI SO	Can you tell me anymore what happened to Con Ed?
	NYPP SPD	It looks like he is all by himself right now; looks like he's separated from the system.
	LI SO	From everybody?
	NYPP SPD	Yep. He didn't shed load when I asked him to; so, it looks like he lost the Linden tie.
	LI SO	I shed load, but it really didn't help.
	NYPP SPD	It helped some. We were going the right way, but he didn't shed fast enough down there.
	LI SO	He was the one who should have shed load.
	NYPP SPD	Well, I asked him to shed load, too. Yeah, besides voltage reduction, but he didn't get it down quick enough, so—.
	LI SO	OK, fine.

TRANSCRIPT OF JULY 13, 1977, TELEPHONE TAPE OF NYPP POOL DISPATCHER

Time	Company and position	Conversation
20:38:05	NYPP PD	Yeah, Jim.
	PJM AID	What are you doing?
	NYPP PD	I lost Indian Point 3.
	PJM AID	Indian Point 3?
	NYPP PD	Yeah, 900 on it.
	PJM AID	OK.
	NYPP PD	Okey, dokey.
	PJM AID	What time you make it?
	NYPP PD	We don't have an official time yet.
	PJM AID	OK.
20:40:36	CE PD	Can you give us a hand at getting 81 deloaded?
	NYPP SPD	Yeah, we were just looking at it there. We are going to cut some of that New England stuff

Time	Company and position	Conversation
		off there. That really should relieve some of it off there. OK?
	CE PD	Alright, Willie.
	NYPP SPD	Fine and dandy.
20:41:16	NYPP PD	I'm going to cut the emergency to PJM; he can get out of it.
	NEC	McGuiness.
	NYPP PD	Jack, the 250 emergency to PJM—.
	NEC	Yeah.
	NYPP PD	I got to cut it right now.
	NEC	Very good.
	NYPP PD	OK.
	NEC	That will help me out.
	NYPP PD	Pull it off as fast as you can. I lost Indian Point, 900, and I got tie problems.
	NEC	Right.
20:41:34	PJM AID	I'm over by about 26 MW actually. If he moves one tap on the tap changer at Linden/Goethals, why, that may get us out of it.
	NYPP APD	Yeah, Dick. He's got a couple of overloads he's working on too right now.
	PJM AID	Alrighty.
	NYPP APD	I think Pete wants to talk to the economy man—don't you, Pete?
20:41:55	NYPP PD	Yeah.
	PJM	Jim, New York wants you.
	PJM AID	Jones.
	NYPP PD	Jim, the 250 emergency I'm getting from NEPEX for you—I've got to cut it right now.
	PJM AID	OK.
	NYPP PD	I got tie problems with this Indian Point going off.
	PJM AID	You want to make it 20:40 then?
	NYPP PD	Yeah.
	PJM AID	OK. Bring us back to 350 at 20 of.
	NYPP PD	Right.
	PJM AID	OK.
	NYPP PD	We won't have it the next hour either.
	PJM AID	OK. Zero, right.
	NYPP PD	Okey, dokey.
20:43:34	NYPP PD	Yes, sir.
	CE PD	It looks like I'm going to have to pick that support power up.
	NYPP PD	OK. How much is it going to be, Jack?
	CE PD	792.
	NYPP PD	792?
	CE PD	Yeah, that is something.
	NYPP PD	You won't have the 37, huh? I guess I can cancel that out, huh?
	CE PD	Oh, boy.
	NYPP PD	OK.
	CE PD	Alright, I'll get these dogs moving up. Right.
	NYPP PD	Okey, dokey.
20:49:53	NYPP PD	Yes, sir.
	O&R SO	Yes, sir, Peter. Did PASNY tell you that we're

Time	Company and position	Conversation
		going to schedule 5 support for the 22d, 23d, and 24th hour?
	NYPP PD	No, he didn't. He didn't give it to anybody.
	O&R SO	Well, I figured I'd give it to you then.
	NYPP PD	Well, all your figures are going to be screwed up because it's not in there. Your 60 assured is.
	O&R SO	My 60 assured is?
	NYPP PD	Right. OK.
	O&R SO	Well, I'll write it down on my sheet and with my inadvertent, it won't make much difference anyway.
	NYPP PD	OK. That's going to be five on the support?
	O&R SO	Right. For the last 3 hours of the night—22d, 23d, and 24th.
	NYPP PD	Right. OK.
	O&R SO	Thank you.
20:52:43	NYPP PD	Yes, sir.
	NM APD	Yeah, Pete. PASNY wants to schedule support power for the next hour.
	NYPP PD	Well, he's been told that he's not allowed to, but he's doing it anyway.
	NM APD	Well, if you ain't going to take it, I ain't going to schedule it. It's as simple as that.
	NYPP PD	I have no way of getting it into the schedule for the next hour.
	NM APD	I already asked him if he cleared it with you; and he said, "Well, John was talking with you on the other phone."
	NYPP PD	John talked to Bill, and Bill told him he can't.
	NYPP PD	You told John, right?
	NYPP SPD	Yeah.
	NYPP PD	John was told he can't.
	NM APD	Can't, huh?
	NYPP PD	Right.
	NM APD	Well, OK. I ain't going to schedule it then.
	NYPP PD	OK.
20:54:54	PJM AID	Jones.
	NYPP PD	Jim, that 200 from Ontario—I'm cutting off on the hour also.
	PJM AID	OK. So we'll be coming to zero looks like on the emergency capacity and energy then, right? We're at 350 right now at 20:40. Was it 20:40 or—?
	NYPP PD	Right.
	PJM AID	That's about it.
	NYPP PD	OK.
	PJM AID	Let's see—the assured—will that come to zero?
	NYPP PD	Nope, I'll leave that there. Right, you'll still have that.
	PJM AID	I'm going to give you a better price on that since you're cutting me. Let's make that—how about—48.5 with my cost.
	NYPP PD	Right. OK.
	PJM AID	Fine, thank you.

Time	Company and position	Conversation
	NYPP PD	Right.
20:56:14	NYPP PD	Hello.
	OH PS	Want another hundred?
	NYPP PD	I'm taking the 200 on that I had going to PJM.
	OH PS	Yeah.
	NYPP PD	We're cutting it off and we're keeping it for ourselves. I lost—I'm having a . . . of a lot of trouble down in the Con Ed area—I lost LILCO tie, and we lost Indian Point, 900.
	OH PS	OK, fine. You don't want to try another 100 economy do you?
	NYPP PD	I'll take another hundred on the emergency, and make it 300 on emergency.
	OH PS	Three hundred on emergency—take your word—holy . . . . I think we can get it over to you.
	NYPP PD	OK. OK. Right.
20:57:12	NM APD	Pete, now they want to take the . . . 37 out of there that they was transferring in the first place.
	NYPP SPD	Tell them we have major problems. We ain't got time to fool around with this stuff. They just lost the Jamaica Valley Stream, the 81 feeder down there. Con Ed is in dire emergency down there.
	NM APD	That's what I'm talking about. They said Con Ed said they couldn't take the . . . 37.
	NYPP PD	Thirty-seven is a . . . in the stream. That 37 don't mean a . . . thing.
	NM APD	Alright.
20:59:20	NYPP PD	Jack, I've got 300 emergency coming from OH in about 1 minute to you.
	CE PD	Alright. Can you get it through the ties?
	NYPP PD	Well, we're going to ship it down there.
	CE PD	Well, I'll tell you—you'll burn them down because I don't think you can get it through.
	NYPP PD	Well, then, you better start shedding some load then.
	CE PD	Alright, we will.
	NYPP PD	OK.
	CE PD	Right.
20:59:57	NYPP PD	Yes, sir.
	O&R SO	Yes, sir, Peter, PASNY just cancelled that support power for those 3 hours.
	NYPP PD	Right.
	O&R SO	OK. Good enough.
	NYPP PD	Right.
21:00:28	OH PS	Production, Ev.
	NYPP PD	Ev, that 300 that I was going to take—emergency—I'm going to have to go to zero on that. What ties are left down there are way over the top. I won't be able to get it in.
	OH PS	OK. So we're taking that 300 right down to zero.
	NYPP PD	Right.
	OH PS	You'll have the 650 assured on.
	NYPP PD	Right.

Time	*Company and position*	*Conversation*
	OH PS	Thank you.
	NYPP PD	OK.
	OH PS	Right.
	NYPP PD	Yes, sir.
21:01:45	PASNY SS	Pete?
	NYPP PD	What, John.
	PASNY SS	Who's this?
	NYPP PD	This is Pete.
	PASNY SS	Leaving that schedule the same for that 22d hour.
	NYPP PD	OK. Good.
	PASNY SS	You can't get anything through, right?
	NYPP PD	Right.
	PASNY SS	So, . . . there's a bunch of . . . phone calls we could have eliminated if we had known that.
	NYPP PD	Yeah, OK.
	PASNY SS	What about the 23d hour?
	NYPP PD	Let's worry about that when we get to it.
	PASNY SS	Well, I don't want to get in this bind again. . . . We're still making phone calls.
	NYPP PD	Well, the . . . tie is overloaded. We're shedding load down there, OK?
	PASNY SS	Alright.
21:17:15	NEC	McGuiness.
	NYPP PD	I don't know if I gave you the price, but 41.27 for the 400.
	NEC	OK. Very good.
	NYPP PD	OK.
21:17:36	OH PS	Production, Ev.
	NYPP PD	Here, Ev—my price for this hour for that 200 economy was 42.08.
	OH PS	OK. The hour we're in—what do we have left?
	NYPP PD	We got the 660 assured.
	OH PS	Yes, 660 assured.
	NYPP PD	. . . and 200 straight.
	OH PS	I cut you off at 200 straight? Well, let's slap it back in there. The only thing we cut off was the PJM cut off the cap. Alright, I show then, if I could, for this hour—I show an 847 schedule.
	NYPP PD	That is correct.
	OH PS	And you are at what price?
	NYPP PD	42.08.
	OH PS	I'll have to get back with my pricing because all my things are screwed up.
	NYPP PD	Right.
	OH PS	Thank you very much.
21:18:54	NYPP PD	Yeah, Kenny.
	LI SO	Can you tell me why the tie went to zero? Did Con Ed lose lines or open at Valley Stream, or what?
	NYPP PD	No, they lost lines—it looks like they lost something else, now. I'll be back to you.
	LI SO	Look at it go out.
	NYPP PD	Yeah.
21:19:10	NYPP PD	Yeah, Keith.

Time	*Company and position*	*Conversation*
	NYSEG SD	23 hour.
	NYPP PD	I'll call you back.
21:19:26	NYPP PD	Yeah, Ken.
	LI SO	Listen, they lost something else.
	NYPP PD	Yeah, we know that.
	LI SO	And I'm all overloaded on CLP quite a bit.
	NYPP PD	OK. Start backing it off. Hit everything you can.
	LI SO	I'll have to start dropping load.
	NYPP PD	OK. Shed load or separate.
	LI SO	Yeah.
	NYPP PD	OK.
21:19:45	NYPP PD	Yes, sir.
	PJM AID	OK. You called here, Pete?
	NYPP PD	We started to call you. Somebody call PJ? Looks like we lost something else down at Con Ed.
	PJM AID	OK.
	NYPP PD	OK.
21:20:46	NYPP PD	Yeah, Bob.
	CH LD	Can you tell me what's happening?
	NYPP PD	We don't know ourselves, but Con Ed is going down.
	CH LD	It's gotta be it; everything is running right through our system.
	NYPP PD	Yes.
	CH LD	And, we don't understand any of this.
	NYPP PD	It's going right down; they lost something else.
	CH LD	And, power is rushing in one end and out the other, and it's going to blow all our stations out.
	NYPP PD	Right. Start backing stuff off.
	CH LD	Yeah. You want more down at Roseton?
	NYPP PD	You want Roseton down some more?
	NYPP PD	Yeah, start backing her off.
	CH LD	OK. I will.
	NYPP PD	Right.
	NYPP PD	He's up to 500 on 901/902.
21:21:24	NYPP PD	Hello. Yeah, Kenny, you going to start shedding that . . . Jamaica?
	LI SO	I'm going to have to open that tie.
	NYPP PD	Go ahead, open it up; save your own system.
21:22:18	NYPP PD	Yeah, Kenny.
	LI SO	I opened the Valley Stream tie.
	NYPP PD	OK.
	LI SO	We'll pick up our own load that we dropped. We are up to 500 on the ties.
	NYPP PD	You're overshooting on Norwalk Harbor now, so start picking up that load.
	LI SO	We are shooting it out there.
	NYPP PD	What time did Jamaica tie open?
	LI SO	21:21.
	NYPP PD	21:21, OK.
21:23:23	NEC	McGuiness.
	NYPP PD	Yeah, Jack, Long Island separated from Con

Time	Company and position	Conversation
		Ed—we had to have them separate. Something else went down in Con Ed; Con Ed's going down.
	NEC	OK.
	NYPP PD	And, he shed quite a bit of load—we don't know how much—but he's picking the load back up and that's getting the tie back. He's starting to head back.
	NEC	Long Island? Long Island shed load and we don't know what Con Ed's doing except just losing and losing, but Long Island shed load and his tie got up too high and separated from Con Ed finally; and now he's restoring his load, so that's getting the cable back. OK.
	NYPP PD	Right.
21:24:26	OH PS	Production, Ev.
	NYPP PD	Ev, I want to cut 200 right away on the assured economy.
	OH PS	OK, coming down.
	NYPP PD	OK.
21:28:08	OH PS	Production, Ev.
	NYPP PD	Ev, I'm going to have to cut the 400 off there.
	OH PS	Another 400 off?
	NYPP PD	Right.
	OH PS	Coming at you.
	NYPP PD	OK.
21:30:14	NYPP PD	Jack, the 400 economy I'm getting—
	NEC	Right.
	NYPP PD	You gotta cut it.
	NEC	Very good.
	NYPP PD	Looks like Con Ed's down the dumper.
	NEC	OK.
	NYPP PD	OK.
21:36:13	LI SO	Hello.
	NYPP PD	Kenny, as you pick this load up, you can keep that Norwalk tie on 144 into you.
	LI SO	I'm going to keep it at zero for a while to cool it down, I think. We were overloaded for quite a while.
	NYPP PD	Yeah.
	LI SO	But, I'm still pumping out to them. If we bring it back to zero anyway—and slowly work it up.
	NYPP PD	Right.
	LI SO	OK.
21:38:10	O&R SO	Do you have any indication line 94 is out?
	NYPP APD	Ninety-four? Y88 is out—I don't have any indication 94 line is out. Is it?
	O&R SO	Well, we think it is because PJ called us and they were . . . in their pants. They wanted us to trip our 69 line so that they could unload their K3410, and boy, this guy was . . . .
	NYPP PD	Well, 94 looks like it's in, but the 93 out of Buchanan is out.

Time	Company and position	Conversation
	O&R SO	Oh, is that what the deal is?
	NYPP PD	Yeah.
	O&R SO	Because we only had about 30 MW on the . . . thing.
	NYPP PD	Yeah, OK. Nothing is showing; that's probably in the instrumentation.
	O&R SO	OK, Peter.
	NYPP PD	What's your firm for the next hour?
	O&R SO	My firm?
	NYPP PD	Yeah.
	O&R SO	The only thing I can see is Con Ed.
	NYPP PD	Zero for him.
	O&R SO	He's going to zero?
	NYPP PD	No way about it.
	O&R SO	I guess he can't get it in right now.
	NYPP PD	Right.
	O&R SO	And I guess I go to—according to this, that is—assured is zero, and my firm is going to be zero.
	NYPP PD	Zero for your DNI. OK?
	O&R SO	Right. Doesn't include assured, right?
	NYPP PD	That goes to zero.
	O&R SO	Oh. PJM going to zero.
	NYPP PD	Yup. I'm going to zero with him.
	O&R SO	How about my Ontario Hydro?
	NYPP PD	I'm going to zero with that.
	O&R SO	Oh.
	NYPP PD	That schedule goes to zero anyway.
	O&R SO	Right. That's what I want to know. Everything's going to zero?
	NYPP PD	Right.
	O&R SO	I can take number 3 off?
	NYPP PD	OK.
	O&R SO	OK. I'll start her down and get her off.
	NYPP PD	Right.
	O&R SO	Thank you.
21:39:35	NYPP PD	Keith, you going to take your firm in the next hour?
	NYSEG SD	The 23d hour.
	NYPP PD	We're going on manual.
	NYSEG SD	Zero on the firm.
	NYPP PD	OK.
	NYSEG SD	And have 70 for sale.
	NYPP PD	I'm not selling any economy.
	NYSEG SD	OK. One hundred forty-three out on the setter.
	NYPP PD	One hundred forty-three, OK.
	NYSEG SD	Alright.
	NYPP PD	'Bye.
21:40:02	NYPP PD	I'm not going to handle any economy at this hour.
	RGE LD	Davis.
	NYPP PD	Yeah, Jack. Figure DNI for the next hour—no economies. We're going to manual.
	RGE LD	You're going to manual?
	NYPP PD	Yeah, Con Ed's down the drain.

Time	Company and position	Conversation
	RGE LD	Con Ed's down the drain?
	NYPP PD	Yeah.
	RGE LD	Oh . . . I got to figure it then.
	NYPP PD	Alright. OK, call me back when you get it.
	RGE LD	OK.
21:42:09	CH LD	Hello.
	NYPP PD	Yeah, Bob.
	CH LD	Yeah, Pete.
	NYPP PD	Figure up DNI for the next hour with no economies.
	CH LD	No economies; I wasn't figuring on selling. OK, 14.
	NYPP PD	Fourteen—in or out?
	CH LD	In.
	NYPP PD	In.
	CH LD	OK, just losses.
	NYPP PD	Right.
	CH LD	No firms either.
	NYPP PD	Right.
	CH LD	I don't want none. Zero on the firms.
	NYPP PD	Right.
	CH LD	Fourteen.
	NYPP PD	OK.
21:42:40	NM APD	Syracuse.
	NYPP PD	Yeah, Jim. Figure your DNI for the next hour with no economy.
	NM APD	No economy at all?
	NYPP PD	Right. Central Hudson's going to zero on his firm.
	NM APD	OK. How about that "Q" power, you want that canned?
	NYPP PD	Go to zero on it.
	NM APD	We're separated with them—I was going to say.
	NYPP PD	Yup.
	NM APD	OK, we'll get a hold of Quebec. I don't know if they can get it stopped within the next hour.
	NYPP PD	Well, tell them Con Ed's down the dumper.
	NM APD	Yeah, just figure a flat nothing.
	NYPP PD	Right.
	NM APD	OK.
21:43:14	OH PS	Production, Ev.
	NYPP PD	Yeah, Ev. For the next hour I'm not going to take any assured or any economy.
	OH PS	OK. We still have 60 or so. We'll take that to zero.
	NYPP PD	Right.
	OH PS	Alright, I've got 50 minus 77—.
	NYPP PD	50 on the transfer?
	OH PS	Yeah, 50 on the transfer.
	NYPP PD	Sixteen on the interruptible.
	OH PS	And this gives you 11 MW.
	NYPP PD	Right. OK.
	OH PS	And—whatever you need, anything—just holler.
	NYPP PD	OK. Right.
	OH PS	Right.

TRANSCRIPT OF JULY 13, 1977, TELEPHONE TAPE OF CON EDISON SYSTEM OPERATOR[1]

Time	*Company and position*	*Conversation*
	O&R SO	Serverage.
20:36:00	CE SO	Yeah, Y88 opened up?
	O&R SO	Well, this is what I am assuming. I haven't heard a thing. I was just trying to get a hold of him before I called you to confirm the . . . thing was off.
	CE SO	I see the breakers are opened up there.
	O&R SO	Yeah, OK.
	CE SO	'Bye.
	O&R SO	I expect 20:37 timewise.
	CE SO	OK, right.
	O&R SO	I don't know what happened.
	CE SO	Right.
	CE SO	Y88 looks open.
20:36:30	CE SO	Indian Point No. 3 off?
	ECC	Yeah.
	CE SO	It tripped.
20:37:57	CE SO	Yeah, Bill.
	WDO	Yeah, Bill, it looks like we lost the entire south bus including unit 3.
	CE SO	Yeah, unit 3 and south bus, huh?
	WDO	Yeah, it looks it according to my Quindar; I'm short.
	CE SO	OK.
	WDO	Now the operator at Buchanan tells me he saw lightning.
	CE SO	Yeah.
	WDO	He's going down now to take a look now to see if there's any damage and—
	CE SO	Alright.
	WDO	Whatever else he can do.
	CE SO	An yes, Y88 is opened at . . . Levittown?
	WDO	Well, I haven't had a chance to check with them yet.
	CE SO	Alright, you got all your breakers open at Dunwoodie?
	WDO	Well, according to the Quindar, the operator is checking them now.
	CE SO	Alright, you got 1, 3, 5, and 6 are opened.
	WDO	One, three, five, and six.
	CE SO	OK.
	WDO	OK.
	CE SO	Right.
20:39:45	CE SO	Yeah, Bill.
	(?)	Yeah, Bill. Did you lose something?
	CE SO	Yeah, we lost something, I'll call you back.
	(?)	OK, 'bye.
20:40:00	NYPP SPD	Hello.

[1]The starting time was 20:35, July 13, 1977. The tapes are 96 seconds slow; 96 seconds must be added to each time given.

Time	Company and position	Conversation
	CE SO	Yeah, on that 81, I need at least 100 MW off it.
	NYPP SPD	Yeah, we're cutting emergency from New England, there Bill, so it should be coming back there.
	CE SO	OK. Are you doing it right away?
	NYPP SPD	Yep, we already cut it, so it should be coming back to you.
	CE SO	OK, 'cause I'm over; the normal is 825 and I'm going to 974.
	NYPP SPD	Yeah.
	CE SO	OK.
	NYPP SPD	You're still below the long time but we've cut the emergency.
	CE SO	Yeah.
	NYPP SPD	So, you should be getting some relief on it.
	CE SO	OK, thank you.
20:41:35	CE SO	Yeah, Bill.
	WES	Yeah, Bill, Danny.
	CE SO	Yeah.
	WES	Bill, we've got nobody in Millwood West. Are your supervisories up? At Millwood West are they showing your breakers open?
	CE SO	Ah, give me a chance; I'll call you right back..
	WES	OK, thank you.
20:42:10	WDO	Lomonaco.
	CE SO	Yeah, 18, 16 shows open, 10 shows open, 12 must have reclosed.
	WDO	You're talking about Millwood?
	CE SO	Yes, breaker 12 shows closed, but its blinking.
	WDO	OK, 18 and 16 show open.
	CE SO	Eighteen and 16 show open and 10 shows open.
	WDO	And 10 shows open.
	CE SO	But 12 must have opened and reclosed.
	WDO	Did you say 12 must have opened and reclosed?
	CE SO	Yes.
	WDO	OK, 12 reclosed.
	WDO	Ladentown is not sure whether those breakers are open on Y88 or not.
	CE SO	They show up here.
	WDO	They do show up?
	CE SO	Yes, I told them that.
	WDO	Yeah, well he says he's not certain.
	CE SO	Well, tell him to get off the . . . pot, for goodness sakes.
	WDO	Well, he says he's going to have someone have a look at it.
	CE SO	Alright, now I told them that the breakers are opened. OK. So now we got all of south Buchanan out, huh?
	WDO	Yeah, that's right.
	CE SO	Alright, so W97 may be alive back to Buchanan, through number 12.
	WDO	That's a possibility.
	CE SO	OK.

Time	Company and position	Conversation
	WDO	Righto.
	CE SO	Right, right.
20:43:44	CE SO	Yeah, Bill.
	NYPP SPD	You getting your turbines on—eh, Willie?
	CE SO	Yes.
	NYPP SPD	Yeah, OK, fine, that ah, that, that 81 is beginning to come down there now a little bit.
	CE SO	Yeah, I see it now. OK.
	NYPP SPD	Right.
20:45:00	PSE&G	Yes, sir.
	CE SO	I got about 300 into, or a little better. Can I leave it there for a little while?
	PSE&G	Yeah, sure.
	CE SO	'Cause I got down on pretty fast time for you.
	PSE&G	Yeah.
	CE SO	I lost all of Indian Point 3 and Y88 and it looks like W98 out of Buchanan—the whole Buchanan South bus is gone—out.
	PSE&G	Goodness.
	CE SO	That's why everything flung around through you into us.
	PSE&G	Yeah.
	CE SO	So we'll see, ah, see, what we can do.
	PSE&G	OK.
	CE SO	Right.
	CE SO	Yeah. Hello, hello.
20:48:00	WDO	Lomonaco.
	CE SO	Yeah, how are you making out?
	WDO	I'm getting a report from the Buchanan operator now—I'll call you back.
	CE SO	OK, good, right.
20:52:15	CE SO	(Dials outside number.)
	(?)	Hello.
	CE SO	Yeah, Charlie.
	(?)	Who do you want?
	CE SO	Mr. Durkin?
	(?)	You must have the wrong number.
	CE SO	I'm sorry.
20:52:50	CE SO	(Dials outside number.)
	CE SO	Six.
	(?)	Your number, please?
	CE SO	Oh, yeah, I'd like to have nine . . . .
	(?)	Your number, please?
	CE SO	This is TR 4-6898.
	(?)	Thank you.
	CSO	Hello.
	CE SO	Yeah, Charlie. (Clicking sound and then busy tone.)
20:54:00	CE SO	Yeah.
	NYPP SPD	Bill, you'd better get that Linden back or you'll lose that baby, too.
	CE SO	Yeah, I just lost 81.
	NYPP SPD	Yeah.

Time	*Company and position*	*Conversation*
	CE SO	Yeah.
	NYPP SPD	You lost the Jamaica tie, too.
	CE SO	Huh?
	NYPP SPD	You lost the Jamaica tie, too.
	CE SO	Which Jamaica tie?
	NYPP SPD	Ah, Jamaica Valley Stream.
	CE SO	Oh, that could be. Alright, but, ah, help me out with the 81/80 feeder, huh?
	NYPP SPD	Yeah.
	CE SO	Right.
20:55:20	CE SO	Yeah.
	NYPP SPD	Bill, you better shed some load until you get down below this thing because I can't pick anything up except from the north, see?
	CE SO	Yeah.
	NYPP SPD	So you'd better get—do something to get rid of that until you get yourself straightened out.
	CE SO	I'm trying, I'm trying.
	NYPP SPD	OK.
	CE SO	Right.
20:56:00	CE SO	Yeah, Bill.
	LI SO	Did you lose something at Jamaica? Our tie went to zero here.
	CE SO	I didn't know. The Jamaica tie, it looks like it did.
	LI SO	It looks like we lost the intertie between you and us.
	CE SO	Yeah, OK, right.
20:56:56	QDO	Hello.
	CE SO	Did you lose 71 and 72 feeder?
	QDO	Yes, we did, we lost at Astoria. Sorry, Hudson Avenue East, we lost 3 and 6 breakers.
	CE SO	Give all you can, I have no time . . . . How about 71 and 72?
	QDO	Seventy-one and 72?
	CE SO	Or 701 or 702 opened up. I don't know.
	QDO	That would be 702.
	CE SO	Seven hundred one and 702 opened up, OK.
	QDO	No, just 702, 'cause just the 3 and the 6.
	CE SO	OK, just give me the times and give me your records on this.
	CE SO	Yeah, I've got to get somebody in to Jamaica to check it.
	CE SO	Right, right, right.
20:57:00	CE SO	Yeah, Bill.
	NYPP SPD	Bill, I hate to bother you but you better shed about 400 MW of load or you're gonna lose everything down there.
	CE SO	Yeah, I'm trying to.
	NYPP SPD	You're trying, all you got to do is hit the button there and shed it and then you worry about it afterwards, but you got to do something or they're going to open up that Linden tie on you.

Time	*Company and position*	*Conversation*
	CE SO	Yeah, right, right.
	CE SO	Yeah, Bill.
	CE SO	Yeah, Bill.
21:00:15	QDO	Yeah, Coffey.
	CE SO	Yeah, on 702, would you try cutting it back in.
	QDO	Cut it back in?
	CE SO	Yeah.
	QDO	OK. They haven't come back with relays—soon as they get to me.
	CE SO	Yeah.
	QDO	OK.
	NYPP SPD	Hello.
21:00:46	CE SO	I look any better?
	NYPP SPD	No, you still got to get rid of about 400, Bill, because you've got. You're 400 over the short-time emergency on that 80 line.
	CE SO	Yeah, that's what I'm saying. Can you help me out with that.
	NYPP SPD	I can't do nothing because it's got to come from the lower part of the State and there's nothing there to help you with. You got to do it . . . .
	CE SO	I got no GT's to put on 'cause they went home.
	NYPP SPD	OK, then you're gonna have to shed load, because that's the only way that things gonna save you.
	CE SO	Yeah.
	NYPP SPD	So you get those . . . things on.
	CE SO	Yeah, right.
	NYPP SPD	I told Long Island to pick up everything that he has. That's the only place I can get into you.
	ECC	Eighty's overloaded.
	CE SO	Anything you can do to help?
	NYPP SPD	There's no way I can help you see. OK, Will?
21:02:20	WES	Hello, Sweet.
	CE SO	Yeah, you're gonna have to cut out 80 for me. I can't hold it, it's much too high on load.
	WES	Which was this?
	CE SO	Feeder 80.
	WES	Feeder 80, you want that cut out?
	CE SO	Yeah, can you cut that out or do you want me to cut it out from here?
	WES	OK, we got nobody in the station. You'll have to do it, let's see; Pleasant Valley, too—yeah, we got nobody in Millwood West yet.
	CE SO	Then I'm gonna have to cut the . . . thing out because I'm overloaded too much.
	WES	OK.
	CE SO	Alright.
21:03:30	NYPP SPD	Yeah, Bill.
	CE SO	I'm going to cut feeder 80. I have no way of deloading it right now. I'm gonna cut it out.
	NYPP SPD	Can't you shed load and relieve it? If you cut feeder 80, then you'll really be in trouble.
	CE SO	Ah, I'll see what I can do.

Time	Company and position	Conversation
	NYPP SPD	Alright.
21:03:59	NYPP SPD	Yeah, Willie.
	CE SO	Can't you have Roseton . . . back off?
	NYPP SPD	I can have Roseton back off, but that's not going to help your 80 line because it's coming down through Ramapo. Going down in . . . .
	CE SO	No, it's coming down . . . from Roseton.
	NYPP SPD	Well, I've asked, I've asked them all to back off up there, but that's not going to help you, Bill, you know.
	CE SO	It should be able to help me if he backs off on their Roseton machines.
	NYPP SPD	Yep. You've got nothing to pick up—see what I'm saying—you need something in the south to ease it off, and there's nothing you can do but shed load down there.
	CE SO	Yeah.
	NYPP SPD	You can't get your turbines on?
	CE SO	It's just the idea. I was figuring on going ahead of the game and letting them go naturally. I'm getting the Narrows put on and the Astoria machines put on.
	NYPP SPD	Yeah.
	CE SO	Yeah.
	NYPP SPD	If you can get them on, then I can back off stuff from the north, see?
	CE SO	Right.
21:04:50	CE SO	Yeah, Bill.
	PGO	You got a minute to tell me what happened?
	CE SO	Who's this?
	PGO	McDucca, operation.
	CE SO	I'm busy right now, I'll call you back.
	PGO	Right.
21:05:00	CE SO	Right.
	CE SO	Yeah, Bill.
	HA	Bill, the only thing we have is GT's. You want us to put the GT's on?
	CE SO	Yeah, put them on.
	HA	OK.
	CE SO	Right.
21:06:13	CE SO	Hello, Bill.
	CSO	Hi ya, Bill.
	CE SO	Hi.
21:06:15	CSO	You got some problems, huh?
21:06:17	CE SO	Yeah, Charlie. Just one moment, huh? I got—I lost Y88 and W98, and it looks like W97 is alive back on one breaker from Millwood. Indian Point—then I got overload, and I got 81 taken down, but it must have been struck by lightning—because 81 went out. I'm overloaded on 80 by 1,430 MW. I'm trying to get everybody back up but I have no GT's. I had Ravenswood GT's go home, and . . . .

Time	Company and position	Conversation
21:06:43	CSO	One thousand four hundred thirty MW's on 80?
	CE SO	Yeah, it's good for normal at 3 hours, 985. I've been pushing everybody to get it down.
21:06:53	CSO	LILCO is still flat out?
21:06:57	CE SO	LILCO, LILCO. Yeah, I lost 702 out of Long Island, that happened too.
21:07:04	CSO	You got 94 in service, too?
21:07:05	CE SO	Y94 is in service.
	CSO	How much is on it?
21:07:08	CE SO	Zero.
	CSO	Zero, how come?
21:07:12	CE SO	It shows balance; W93 shows balance too.
21:07:14	CSO	Something must be out up there then.
21:07:15	CE SO	Yeah, must be, I haven't had a chance to get everything up. We got people running all over the place. So I got overloads on W80; feeder 80 is 1,480; it's coming down a little bit, now, but still way over on the 3-hour rating, by 500, you know.
21:07:27	CSO	Yeah, it's over the 20-minute rating.
21:07:29	CE SO	Yeah, right. So I figure I ought to cut it out, huh?
21:07:33	CSO	Where's the power going to go to if you cut it out?
21:07:38	CE SO	That's it.
21:07:39	CSO	You can't cut it out—
	CE SO	No.
	CSO	You either go into voltage reduction—
	CE SO	And the Linden tie is way up there. I had to back off, because he was up to 900 MW; the guys down there are about 500.
21:07:46	CSO	Ask him if he can take that up to 700. OK?
	CE SO	Huh?
	CSO	Let him ease that up to 700.
21:07:55	CE SO	Linden and the pool just called and wants us to go into voltage reduction.
21:07:57	CSO	OK, how long have you been with this loading on the feeder?
	CE SO	8:38.
	CSO	8:38.
	CE SO	Well, no, it was before that 'cause they . . . .
21:08:05	CSO	Push button number 3.
21:08:09	CSO	. . . and give me the time there.
	CE SO	FC 3?
	CSO	Yeah.
	CE SO	FC 3?
	CSO	Right.
	CE SO	The time.
	CSO	What time did the feeder get into overload?
21:08:21	CE SO	Feeder 80?
21:08:22	CSO	Yeah, is the time there?
21:08:28	CE SO	20:58.
	CSO	20:58.
	CE SO	Correct.
	CSO	8:58.

Time	Company and position	Conversation
	CE SO	Yeah.
	CSO	So you've been this way about 10 minutes?
21:08:30	CE SO	Yeah.
21:08:38	CSO	How's it? What's the loading—is it going down at all?
21:08:41	CE SO	Yeah, well it has gone down, it's gone down to 1,400 now; it was higher.
21:08:44	CSO	Are the machines moving?
21:08:46	CE SO	Yeah, we're getting everybody up as much as we can—I have no Ravenswood GT's or Gowanus GT's. I had let them go home earlier, not knowing this was going to happen.
	CSO	OK.
21:08:57	CE SO	Yeah, I got max generation alarm up, too.
21:09:05	CSO	Has Jack called on the stations to tell them it was an extreme emergency? Ask them to move as fast as possible.
21:09:11	CE SO	Yes, right.
	CSO	OK.
	CE SO	Right, we're down at 1,388 now.
21:09:15	CSO	What's the 20-minute rating on that feeder? What's the . . . ?
21:09:20	CE SO	The 20-minute rating, limits the 20 minute, 1,790.
21:09:24	CSO	That's the current, right?
21:09:28	CE SO	Yeah. The current is running around 2,590; 19 the amperage.
21:09:30	CSO	Did you get the current off the supervisory?
	CE SO	Huh?
	CSO	Getting the current off the supervisory.
21:09:36	CE SO	Yeah, just the tube, feeder 25 is about 475. Now, if I pick up on the Linden tie I got—
21:09:49	CSO	. . . ask Cockerham to pick up on the Linden tie.
21:09:51	CE SO	I'm gonna do it now.
21:09:52	CSO	OK, pick up on the Linden tie. Try and get 100 MW or so on it.
21:09:57	CE SO	I got 445 on it now.
21:09:59	CSO	Pick up at least 100; pick up 150 if you can. Tell Cockerham to tell New Jersey that we're in danger of shutting down all of New York.
	CE SO	Yeah.
21:10:07	CSO	OK, we've got to take some power in.
21:10:11	CE SO	Tell Linden I got to take some more power in—we're in danger of losing it. Everything's cascaded around here.
	CSO	You've got a problem on 94 and 93.
21:10:24	CE SO	Yeah, 702 went out on me also.
	CSO	Don't—let's not worry about that.
	CE SO	No, I'm not worrying about this. I'm not even . . . paying attention to it.
	CSO	What's Linden at now?
21:10:33	CE SO	We've got 473, and I'm taking in some more.
21:10:39	CSO	Just keep moving it—it will move very slow.
21:10:42	CE SO	Yeah, its 467, 486, 491. She's swinging back and

Time	Company and position	Conversation
		forth. Pool wanted me to go into voltage reduction, too.
21:10:57	CSO	That's because of the feeder.
	CE SO	Huh?
	CSO	That's because of the feeder.
	CE SO	Yeah.
	CE SO	What?
	ECC	500.
	CE SO	He said no more than 500.
	ECC	No.
21:11:06	CE SO	He said no more than 500—I've got 510.
21:11:08	CSO	OK. What do you have on the feeder?
	CE SO	Let me go back over here and look.
21:11:12	CE SO	I'm down to 1,325.
21:11:15	CSO	We've got to get more off; we're going to have to go into voltage reduction.
21:11:17	CE SO	Yeah.
21:11:18	CSO	OK.
	CE SO	Yeah.
	CSO	Take 5 percent to begin with.
21:11:21	CE SO	On everything?
21:11:23	CSO	Yes, everything—the whole system, right now.
21:11:27	CE SO	Alright, tell them I want voltage reduction 5 percent.
21:11:46	CSO	What's the system load now?
21:11:52	CE SO	Fifty-seven, call it 5,800, and we're in 5 percent now.
21:12:09	CSO	Have Jack tell LILCO to take all the power they can in on the Norwalk Harbor tie.
	CE SO	Yeah.
	CSO	Right up to the normal rating.
21:12:30	CE SO	Jack, have Long Island take in all the power they can on Norwalk tie, all the power they can.
21:12:41	CE SO	I better have the stations go into the 5 percent—also, right, the generating plants.
	CSO	Yeah.
	CE SO	Everybody on 5 percent—the generating stations also; if they're not on 5 percent already.
21:13:00	CSO	Everything is in 5 percent?
21:13:03	CE SO	I'm doing it. I'm getting everything going, 110th Street. I'm at now . . . Cherry Street.
21:13:36	CE SO	Alright, I've got everyone on this circuit number 1; now I'm going over to circuit 2.
21:13:42	CSO	How's 81, is it coming down at all?
21:13:45	CE SO	Yeah, I'm down to 1,286.
21:13:59	CSO	Is there a Manhattan D.O. there that can push buttons?
21:14:03	CE SO	Yeah, Walter. Yeah, Buchanan, White Plains—keep going, put them on 5 percent, huh?
	CSO	Hold the button till the light blinks.
	CE SO	I can't hear you.
21:14:04	CSO	Tell him to make sure he holds the button until the light blinks.

Time	Company and position	Conversation
21:14:14	CE SO	So I am not lighting White Plains and Buchanan, because Buchanan, I don't know which way it is.
21:14:26	CSO	Don't worry about that.
	CE SO	I'm not.
21:14:30	CSO	Go back to Linden now, because you might have unloaded Linden some.
21:14:32	CE SO	Yeah, I have to remember Jamaica didn't do into it. Try North Queens, hold the button 5 percent until you get it, OK.
	CE SO	Linden's 486, now.
21:14:52	CSO	Give it another shot; get it up to at least 500.
21:15:00	CE SO	Yeah, right.
21:15:10	CE SO	I have it down to 1,270 on 80. We have a lot to go yet.
21:15:14	CSO	We've got 200 MW to go to get it down . . . .
21:15:20	CE SO	Yeah, about 500—give it another shot. It's the same. OK, you got them all, Lou?
	MDO	No, how the . . . do you know if they go in. Nothing but the purple comes up. It doesn't come up in North Queens.
	CE SO	Alright, just keep a record. I'm going to Corona. When it comes up about five, the purple shows up. See it.
	MDO	Good, OK.
	CE SO	Alright, now it's still showing 1,270 on 80.
	CSO	Did you get through the 5 percent yet?
21:15:47	CE SO	We're almost through it.
	CSO	You don't have enough; go to 8 percent next.
	CE SO	OK and, ah, will you retie that X28 some more? Push it over 'til he pushes 80.
21:16:10	CSO	Say, Bill.
	CE SO	Yes.
	CSO	Take a look at 77 feeder coming into Ramapo. Does that have any flow on it?
21:16:20	CE SO	Seventy-seven—no, don't show much load on it—it's got about 300 or 400 MW.
	CSO	OK. I was wondering if maybe something opened up north.
21:16:28	CE SO	No, I haven't got all my picture, on what the . . . happened, Charlie.
	CSO	No, I know.
	CE SO	One thousand two hundred thirty-eight we're down to now.
	CE SO	Five percent.
	ECC	I've gone through the ones that didn't come in. How about Millwood West? That's 5 percent?
21:16:37	CSO	Forget Millwood West.
	CE SO	Huh, forget about that; don't worry about that. OK, that's it then, huh.
21:16:43	CE SO	We're only going for . . . go 8 percent then, huh? Go 8 percent all around. Start with this one here. Switch 1, start with Avenue A . . . .

Time	Company and position	Conversation
	ECC	OK.
	CE SO	Eight percent.
21:16:53	CSO	Keep your time on that, yeah.
21:16:57	CSO	Are the machines all the way up to maximum, or what?
21:16:59	CE SO	I got the maximum on, and everything is up as high as they can get it.
21:17:00	CSO	Nobody's moving anymore?
21:17:04	CSO	No, everybody's is up to max, huh, John?
	CSO	How about Ravenswood 3?
	CE SO	Everybody's up to max generation, huh, John?
	CE SO	They're all the way up.
21:17:05	CSO	How about Ravenswood 3?
	CE SO	He's at his . . . .
	CSO	Tell him to start easing up—you know—you're going to lose the whole thing, you know.
21:17:23	CSO	Tell him to start getting up, too.
21:17:25	CE SO	Yeah, he is up there.
	CSO	1,000.
	CE SO	He's not good for 1,000.
21:17:28	CSO	Tell him its a dire emergency; if he can give us anymore, give it to us.
21:17:32	CE SO	Right.
	CSO	OK.
	CE SO	Tell Ravenswood to give anymore if he can—it's a dire emergency.
21:17:38	CSO	OK. How about East River 5 and 6?
21:17:39	CE SO	East River 5 tripped; 6 and 7 are on the way up.
21:17:43	CSO	They're on the way up.
	CE SO	Yeah.
	CSO	How about Waterside 14 and 15?
21:17:46	CE SO	Fourteen is all the way up.
	CSO	They are all the way up?
21:17:50	CE SO	Yeah. Could I put you on hold 1 minute, Charlie?
	CSO	Sure.
	CE SO	Right.
	WAT	. . . .
21:18:12	CE SO	Can you give me as much as you can on that generation—pick it all up?
	WAT	Right.
	CE SO	Are you way up?
21:18:13	WAT	We're all the way up unless you can cut the steam back.
21:18:15	CE SO	Ralph, can you cut steam back so I can get more out of Waterside?
	ECC	Waterside?
	CE SO	Yeah, for Waterside.
21:18:20	CE SO	Pick it up when he cuts back.
	WAT	OK.
	ER	Wise.
21:18:30	CE SO	Yeah, Wise. Bill, pick up everything you can, huh?
21:18:31	ER	Yeah, that's what I'm trying to do.
21:18:36	CE SO	Now, hold it. Yeah, I think we lost 80, Charlie.
21:18:40	CSO	Eighty-one?

Time	Company and position	Conversation
21:18:41	CE SO	Yeah, 80 just opened up.
21:18:42	CSO	Eighty-one or 80?
21:18:43	CE SO	Eighty-one was opened before.
21:18:45	CSO	OK. It was feeder 80 that was bad?
21:18:47	CE SO	Eighty-one opened earlier, and we just now lost 80.
21:18:50	CSO	What's on the Linden tie?
21:18:52	CE SO	Oh, my God—Linden tie is up to 743.
21:18:56	CSO	Seven forty-three?
21:18:57	CE SO	Oh, wait a minute now, 906.
21:18:58	CSO	Nine hundred six?
21:18:59	CE SO	Yes, and I'm still getting down to 8 percent.
21:19:10	CSO	Tell the Manhattan D.O. to get over to that board and try closing on anything he can . . . . 80 and 81 out of Pleasant Valley.
21:19:16	CE SO	Yeah.
	CSO	Try to put them back in again.
	CE SO	Right, OK. Try to reclose 80 and 81.
21:19:38	CSO	Hey, Bill.
	CE SO	Yes.
	CSO	You got to get the Linden tie down, if there's no flow on 80. Look at your meters on the mimic.
21:19:42	CE SO	There's no flow on 80.
21:19:43	CSO	Eighty and 81?
21:19:47	CE SO	Eighty and 81. Yes, they're all out.
21:19:48	CSO	They're all out? OK, shed load.
	CE SO	Yeah.
	CSO	Start with the 4 kV and drop it until you get the Linden tie down to pick up 700 MW.
21:19:53	CE SO	Yeah, can back it off now?
21:19:55	CSO	It won't do you any good, all you have left is 11 and 16.
21:19:58	CE SO	Alright.
21:19:59	CSO	What are they up to?
21:20:00	CE SO	Eleven and 16?
21:20:05	CSO	Yeah, are they off? How are they?
21:20:07	CE SO	They don't look too bad.
21:20:08	CSO	Well you can try backing off, but I don't think you're gonna get anywhere with it.
21:20:10	CE SO	No, something else just went out—oh, he's just trying the breakers. Yeah, he's just trying . . . stay in.
21:20:18	CSO	Now you start—you're gonna drop load—I don't think there is anything else you can do. Do you?
	CE SO	No.
21:20:26	CSO	I mean you could move the angle regulator, but if it goes, you're gonna . . . kill 11 and 16. They'll go next.
21:20:28	CE SO	Yeah, what am I gonna drop it from then?
21:20:31	CSO	Any place, start with the 4 kV, you know that's all I can tell you.
21:20:37	CSO	You got no flow on 80, right.
21:20:39	CE SO	No flow on 80, right.

Time	Company and position	Conversation
21:20:40	CSO	Nothing on 81.
21:20:41	CE SO	Nothing on 81.
21:20:43	CSO	You got nothing on 93?
21:20:45	CE SO	Ninety-three or 94.
21:20:46	CSO	Nothing at all, right?
	CE SO	Nothing at all.
	CSO	Nothing on 88?
	CE SO	Nothing on 88.
21:20:49	CSO	And the Linden tie is at 900 MW?
	CE SO	That's right.
21:20:54	CSO	OK, it's just not going to last long.
	CE SO	Yeah, I am . . . .
21:20:55	CSO	OK.
	CE SO	Yeah.
21:21:00	CSO	So the only thing you can do is try to move it—give it a couple of shots and see what it will do.
21:21:02	CE SO	He's trying, but it keeps cutting out. I think—now how about the 4 kV?
21:21:05	CSO	Right, OK, your gonna have to get rid of load, right? But the machines aren't moving up, right?
21:21:10	CE SO	No.
21:21:16	CSO	Well, then, we can't let the . . . if the Linden goes. That 900 MW is going to show up on 11 and 16.
21:21:20	CE SO	Yeah.
	CSO	They're going to open up, and you're to go on automatic load shedding.
	CE SO	Yeah.
	CSO	OK.
21:21:25	CE SO	But, Charlie, on the 4 kV, where can I cut it out?
21:21:26	CSO	Anywhere—Elmsford, White Plains, Buchanan.
	CE SO	Elmsford, Pleasantville.
21:21:29	CSO	Right. You got them all right there. Pleasantville—just start with the 4-kV panel and start pushing buttons until you get Linden down.
21:21:37	CE SO	Yeah. I'm trying.
	ECC	Looks like 80 is in.
21:21:49	CE SO	No, 80's not in.
21:21:54	CE SO	Pleasantville.
21:21:58	CSO	Yes, just drop them, that's all. Keep dropping them until that Linden tie comes back to 700.
21:22:05	CE SO	Washington Street.
21:22:31	CSO	Do whatever you have to do. We haven't got the time to worry about which one.
	CE SO	Right.
21:22:32	CE SO	It won't trip the son of a gun, Elmsford.
	CSO	Just keep going. Give it a shot—if it won't go, go on to the next one.
	CE SO	What the . . . talking about, too.
21:22:43	CSO	Any, any you got Pleasantville—White Plains, Elmsford, Buchanan, Pleasantville.
21:22:49	CE SO	Pleasantville, I'm getting it.
21:22:53	CSO	Granite Hill.

Time	Company and position	Conversation
21:22:54	CE SO	It won't trip the breakers . . . the area trip.
	ECC	I got a guy in the station.
	CSO	What's the Linden tie at now?
	CE SO	On the trip the 4 kV—Pleasantville, Elmsford—all of them.
	ECC	Oh, OK.
	CE SO	Yeah.
	CSO	What's the Linden tie at now?
	CE SO	I was trying to get the area Linden tie?
	CSO	Yeah.
21:23:13	CE SO	Linden tie's at 1,202.
21:23:17	CSO	One thousand two hundred megawatts.
	CE SO	Yes.
21:23:24	CSO	Just keep going. Just keep shedding load until you get it . . . .
	CE SO	Washington Street, area trip.
	CSO	How about 11 and 16, what are they at?
21:23:35	CE SO	Eleven and 16 shows around . . . way the up there about 300 MW. Washington Street—
21:23:41	CSO	You sure that's 1,200 MW on the Linden tie?
21:23:46	CE SO	Yes, A2253 it's 1,212 MW—amperes at 1,272.
	CSO	What says this?
	CE SO	Huh?
	CSO	What are you reading?
21:23:56	CE SO	On the oscilloscope, on the computer, yeah.
21:23:59	CSO	OK. What's . . . the strip chart on the mimic say? Does that confirm it?
21:24:09	CE SO	You mean on the computer?
21:24:12	CSO	No . . . on the mimic board—what does the strip chart say? The Linden tie?
21:24:18	CE SO	On the mimic board, yes.
	CSO	Yes?
21:24:21	CE SO	Hold on, it reads about the same.
21:24:35	CSO	One thousand two hundred megawatts.
	CE SO	Yeah.
21:24:41	CSO	OK, that tie is going to blow. Just keep shedding load—I'm going to hang up on you, OK?
21:24:42	CE SO	Yeah.
	CSO	You just keep shedding load.
	CE SO	Yeah.
	CSO	OK, until you get that thing down.
	CE SO	Right.
	CSO	Right.
	(?)	Hello, Bill, I've had it.
	(?)	Yeah, Bill, Bill.
21:29:40	PSE&G	I'll have to call you, buddy. What have you got?
	CE SO	I lost the Linden tie, it looks.
	PSE&G	Twenty-two fifty-three is out. You lost the whole Linden 230 bus.
21:29:43	CE SO	Right, OK.
	(?)	Yeah . . .
21:30:40	CE SO	Will you transfer number 5 . . . to the east yard, right away?
	(?)	Yeah, OK.

Time	Company and position	Conversation
	CE SO	Right away.
	CE SO	Yeah, Bill.
21:32:20	CE SO	Did number 2 trip at Astoria?
	(?)	. . . .
	CE SO	Did number 2 trip at Astoria?
21:32:32	AST GTs	I lost 20.
	CE SO	You did, huh?
	AST GTs	Yes, sir
	CE SO	Thank you.
	(?)	. . . .
	CE SO	Thanks.
	AST GTs	Bill speaking.
	CE SO	Bill, will you please transfer number 40 to the west yard, please?
21:32:40	AST GTs	Number 40 to the west yard.
	CE SO	Right, right away.
	AST GTs	Right, right away, OK.

TRANSCRIPT OF JULY 13, 1977, TELEPHONE TAPE OF CON EDISON POWER DISPATCHER[2]

Time	Company and position	Conversation
	CE PD	Cockerham.
	QDO	Hello, Jack, Bob.
20:38:15	CE PD	Yeah.
20:38:16	QDO	Hey, Jack, feeder 42—I've got a fault detector relay target came up—nothing tripped out.
20:38:26	CE PD	Uh, uh.
20:38:27	QDO	OK.
	CE PD	Alrighty.
	NYPP SPD	Yes, sir.
20:39:17	CE PD	Yeah! Ah. Could you give us a hand in getting 81 deloaded?
20:39:19	NYPP SPD	Yeah, we're just looking at it there. We are going to cut some of the New England stuff off there. That'll, ah, relieve some of it off there.
20:39:27	CE PD	Ahuh.
20:39:28	NYPP SPD	OK.
	CE PD	Alright, Willie.
20:40:41	CE PD	Yes, sir.
20:40:43	PASNY LD	Well, I still haven't heard from Indian Point 3, so—
20:40:45	CE PD	You haven't?
20:40:54	PASNY LD	No, not a word.
	CE PD	Oh, boy!
	PASNY LD	I assume he's still down there someplace.
	CE PD	Yea.
	PASNY LD	Well, anyway, I guess you're going to attempt to try and support that this hour we're in now—

[2]The starting time was 20:35. The tapes are 96 seconds slow; 96 seconds must be added to each time given.

Time	Company and position	Conversation
		right, that is that the way we've been doing that—preferred customer load.
20:41:06	CE PD	Ah, to tell you the truth, it beats the . . . out of me.
20:41:09	PASNY LD	Yeah, I mean, like, that 792 preferred customer load that you would pick up to support for that hour.
	CE PD	Uh, uh.
	PASNY LD	And then I'll try—I'll pick up as much as I can the next hour. I can't pick up that 770.
	CE PD	Alright.
	PASNY LD	But I'll . . . get back to you, and pick up as much as—you know—as I can.
20:41:23	CE PD	Uh, uh.
20:41:25	PASNY LD	Is there any limits on going to the power itself?
20:41:31	CE PD	Oh, yes. I mean if you're gonna bring it into my system, please let me know, because . . . .
20:41:39	PASNY LD	Oh, yes. Thats what I'm saying. I mean, before I up it I'll get back to you just before the hour.
	CE PD	Alright.
	PASNY LD	For the 22d hour and . . . .
20:41:42	CE PD	Alright, good enough.
20:41:43	PASNY LD	And we may have to ask for support on that Fitz load you know.
	CE PD	Yeah, alright.
20:41:45	PASNY LD	OK.
20:41:47	CE PD	I'll pick it up.
20:41:57	NYPP APD	Yes, sir.
	CE PD	Yeah, it looks like I'm gonna have to pick that support power up.
20:42:01	NYPP APD	OK, how much is it gonna be, Jack?
20:42:03	CE PD	Seven hundred ninety-two.
20:42:05	NYPP APD	Seven hundred ninety-two.
20:42:06	CE PD	Yeah, that is something.
20:42:08	NYPP APD	You won't have the 37 huh? I guess I can cancel that out, huh?
20:42:18	CE PD	Ha, ha. Oh, boy.
20:42:21	NYPP APD	OK.
20:42:23	CE PD	Alright, I'll get these dogs moving up.
	NYPP APD	Right.
	CE PD	Righto.
	NYPP APD	Okey, dokey.
20:42:52	CE PD	Cockerham.
	AST GTs	Cockerham, I got bad news—dropping load on number 10 again.
20:42:56	CE PD	Oh, man.
20:42:57	AST GTs	Yeah, I know, I'm sorry, babe.
	CE PD	OK.
	AST GTs	Alright.
20:42:59	CE PD	Yeah, sure.
	AST GTs	OK.
	AST GTs	Adams.
20:44:05	CE PD	Yeah, Adams, bring your GT's in, your Pratts.
20:44:10	AST GTs	All of them?
20:44:12	CE PD	Yeah, anything you can give me. Right.

Time	Company and position	Conversation
20:46:33	CE PD	Yes, sir.
	(?)	. . . .
	CE PD	Indian Point.
20:46:37	(?)	OK, sir, two?
20:46:47	CE PD	No, three.
20:46:48	(?)	Three, OK.
20:49:51	CE PD	Cockerham.
	AST GTs	On these units, Cockerham, do you want base load?
20:49:52	CE PD	Yeah, sure.
20:49:53	AST GTs	Okay, we got four coming in.
20:49:54	CE PD	Good enough. Thanks, pal.
	AST GTs	OK.
20:50:50	CE PD	Yes, sir.
	PASNY LD	Yeah, okay now, ah, we'll get that support out of the way for 22—ah, that would be 10, 11, and 12 o'clock tonight. Fitzpatrick—support—we'll put 60 in there each hour from you.
20:51:06	CE PD	Ah, we're gonna segregate it, right? Oh, wait awhile. I got it, 60 for—
20:51:11	PASNY LD	. . . 10, 11, and 12 o'clock.
20:51:13	CE PD	Alright, I got you.
20:51:20	PASNY LD	OK, now if I can find the right sheet here. Ah, now for that 10 o'clock hour, I'll see if I can—send 500 down.
20:51:26	CE PD	From Niagara?
20:51:27	PASNY LD	Yeah.
20:51:28	CE PD	No way.
20:51:29	PASNY LD	No way? OK, this is what we want to know.
20:51:31	CE PD	No way.
20:51:32	PASNY LD	OK, so what can I send you down?
	CE PD	I beg your pardon.
	PASNY LD	How much could I send down?
20:51:39	CE PD	Nothing, because we had to back off on the stuff coming from the north—none, not a thing.
20:51:45	PASNY LD	Oh, I see. No, OK, we can't . . . we owe nothing through there.
	CE PD	No, sir.
	PASNY LD	OK.
20:51:49	CE PD	Our ties are laying on the peg.
20:51:50	PASNY LD	Alright, OK.
20:51:54	CE PD	Pool had to cut us back.
	PASNY LD	Yeah, OK.
	CE PD	Alright.
	PASNY LD	Alright, then.
20:52:01	CE PD	So, ah, for, ah, 9 o'clock—for 10 o'clock, it will be 770?
20:52:10	PASNY LD	770.
	CE PD	Alright.
	PASNY LD	11 o'clock, 728.
20:52:12	CE PD	Alright.
20:52:18	PASNY LD	12 o'clock, 694.

Time	*Company and position*	*Conversation*
20:52:23	CE PD	Alright, very good.
20:52:24	PASNY LD	OK.
20:52:25	CE PD	And, ah, you're gonna have anything for nine?
20:52:32	PASNY LD	Nine, ah, well, I was . . . shipping down 56 that hour. That's all I was shipping, right?
20:52:40	CE PD	Uh, uh.
20:52:42	PASNY LD	For nine so, ah, I guess you're gonna have support the rest of it for that hour.
20:52:49	CE PD	Alrighty, ah, tell you what, you calculate it and I'll write it down, how's that?
20:52:53	PASNY LD	OK, fine, whenever I get the, whenever I get the—
20:52:55	CE PD	Whenever you get a chance.
20:52:58	PASNY LD	Yeah, I haven't even talked to him yet.
20:53:01	CE PD	Yeah, I know what you mean.
20:53:03	PASNY LD	I'll call you back.
20:53:04	CE PD	Alright, good enough.
20:53:48	CE PD	Cockerham.
20:53:49	PASNY LD	Yeah, cancel that 60 support, then—for 20, the last 3 hours of the day, OK?
20:53:54	CE PD	Alright.
	PASNY LD	OK, fine.
	CE PD	Good enough.
	PASNY LD	Yeah.
20:54:59	Narrows	Yes, sir.
20:55:00	CE PD	Yeah, give us both barges right away.
20:55:01	Narrows	OK.
20:55:02	CE PD	Right.
	CE PD	Cockerham.
20.56:30	CE PD	Hello.
	CE PD	Cockerham.
20:56:30	ER 5	Wise.
	CE PD	Yes.
20:56:37	ER 5	We just blew a tube on number 50.
20:56:40	CE PD	Holy . . . .
20:56:42	ER 5	Yeah, I know.
20:56:44	CE PD	Alright, you're coming off, huh?
20:56:45	ER 5	Yeah, she's off. Yeah.
20:56:49	CE PD	She's off?
	ER 5	Yeah.
	CE PD	Alright, what time you gonna make it?
	ER 5	No . . . tube blown is all.
	CE PD	OK. What time you gonna make it?
20:56:59	ER 5	We're gonna make it, ah, 8:58.
20:57:01	CE PD	Eight fifty-eight.
20:57:02	ER 5	Right.
	CE PD	Good enough.
20:57:43	CE PD	Cockerham.
	NYPP APD	Jack, I got 300 coming—emergency out from Ontario Hydro in about 1 minute.
	CE PD	Alright.
	NYPP APD	. . . to you.
20:57:47	CE PD	Alright, can you get it through the ties?

Time	*Company and position*	*Conversation*
20:57:51	NYPP APD	Well, we're gonna ship it down there.
20:57:53	CE PD	Well, I'll tell you'll burn 'em down because I don't think you can get it through.
20:57:59	NYPP APD	Oh, well, you better start shedding some load then.
20:58:01	CE PD	Alright, we will.
20:58:02	NYPP APD	OK.
20:58:04	CE PD	Righto.
	NYPP APD	Right.
20:58:08	CE PD	Cockerham.
20:58:10	RAV 3	. . . 7W, can you raise it 4 taps?
20:58:12	CE PD	Four taps?
20:58:13	RAV 3	We're down to minimum now.
20:58:14	CE PD	Alright, good enough.
20:59:21	CE PD	Cockerham.
	QDO	Hello, Jack, Bob.
	CE PD	Yeah, Bob.
	QDO	OK. Hudson Avenue East Breakers 3 and 6 opened auto at 8:56.
20:59:30	CE PD	Which ones?
20:59:31	QDO	Three and 6.
	CE PD	Three and 6 at what time?
20:59:41	QDO	At 8:56.
	CE PD	Right.
	QDO	And that's feeder 702 right?
20:59:43	CE PD	Seven hundred two, right.
20:59:45	QDO	The other end of that, up at Jamaica—
	CE PD	Huh, huh.
	QDO	In service up there.
20:59:50	CE PD	Oh, alright, alright.
20:59:52	QDO	But now 701, the operator at Hudson Avenue East, says that 701 feeder, the companion feeder, is overloaded now.
20:59:59	CE PD	Right, sure.
21:00:01	QDO	OK.
21:00:02	CE PD	OK.
	QDO	Righto.
21:02:30	CE PD	Cockerham.
21:02:31	AK 2	Ah, this is Lynch. We got 136 on line. Could you help us out a little bit?
21:02:36	CE PD	Alright, good enough, we'll try our best.
21:02:38	AK 2	OK.
	CE PD	Righto.
21:02:51	CE PD	Cockerham.
21:02:52	Narrows	How many megawatts do you want?
21:02:53	CE PD	The whole . . . thing. Anything you can give me.
21:02:56	Narrows	OK.
21:02:57	CE PD	Righto.
21:03:13	SIDO	Hello, Willis.
21:03:16	CE PD	Yeah, uh, get somebody over there to close those reactors at Goethals.
21:03:19	SIDO	OK, John just stepped out a minute. I'll give him the message.

Time	Company and position	Conversation
21:03:22	CE PD	Alright.
21:03:23	SIDO	What reactors at Goethals?
21:03:24	CE PD	Have him call me back.
21:03:25	SIDO	OK, I'll do that.
	CE PD	Right.
	AST GTs	Adams.
21:04:50	CE PD	Yeah, Adams bring all your GT's in, Westinghouse's included.
	AST GTs	OK.
	CE PD	Right.
21:05:00	CE PD	Cockerham.
	AST GTs	Cockerham, what's up?
21:05:01	CE PD	We lost Indian Point 3. Bring them in, huh, as quick as you can.
21:05:05	AST GTs	We got everything here.
21:05:06	CE PD	Alright.
21:05:08	AST GTs	You gotta tell—we got 160, everything I got.
21:05:12	CE PD	How about that, alright, what times you got?
	AST GTs	Right. OK, I'm sorry, Dan, OK.
21:06:06	QDO	Yes, Coffey.
	CE PD	Yeah, Bill. Ah, Bob, did you cut that 702 in?
21:06:09	QDO	No, not yet, it's across the street. They're out in the yard over there now. We're trying to get in touch with them.
21:06:16	CE PD	OK, get them in as quick as you can.
21:06:17	QDO	Sure will.
21:07:22	CE PD	Yes, sir. Hello. Yes, sir.
21:07:25	NYPP SPD	Bill. Tell Bill to go into voltage reduction immediately down there.
21:07:29	CE PD	Alright.
21:07:30	NYPP SPD	OK.
	CE PD	Good enough.
21:07:33	CE PD	Cockerham.
21:07:35	(?)	Cockerham, you want the gas turbine?
21:07:37	CE PD	Ah, no.
21:07:38	(?)	OK.
21:07:39	CE PD	Right.
21:08:36	CE PD	Cockerham.
21:08:38	QDO	Yeah, hey, Jack. Also Farragut—the operator reports a drastic drop in load on feeder 45 and 46.
21:08:45	CE PD	Forty-five and 46.
21:08:48	QDO	Right, the other end of those two is that M51 and M52.
21:08:50	CE PD	Yeah, I know we're trying to deload 80.
21:08:53	QDO	Yeah, OK. Just wanted to let you know.
21:08:55	CE PD	Now, how about that Jamacia?
21:08:56	QDO	Jamaica is in, 702—that stayed in Hudson Avenue—is the one I'm waiting for.
	CE PD	OK, pal.
	QDO	OK.
21:10:23	PSE&G	Are you looking for a number?
21:10:33	CE PD	No, sir. I'm, ah, I just gonna, I'm gonna have to,

Time	Company and position	Conversation
		we're going to have to, take some more in on the Linden tie because we're in jeopardy with our ties up north.
21:10:36	PSE&G	Well, how much more you got, about 460, now?
	CE PD	Uh, uh.
21:10:40	PSE&G	And its only good for 500.
21:10:41	CE PD	Alright, we won't overload it.
21:10:43	PSE&G	You won't overload it.
	CE PD	Right.
21:10:46	PSE&G	You'll go up to 500 and leave it there?
21:10:47	CE PD	Right.
21:10:48	PSE&G	And when you get a time, when you get a chance you'll let me know what happened?
	CE PD	Sure thing.
	PSE&G	Alright.
	CE PD	Thank you.
	PSE&G	Righto.
21:11:54	CE PD	Cockerham.
21:11:55	WAT	Cockerham, Gallagher, we can't help you out over here with load unless we cut steam you know.
21:12:01	CE PD	Alright, good enough.
21:12:03	WAT	Alright.
21:12:04	CE PD	Yeah, you're alright.
	WAT	OK.
	CE PD	Righto.
21:12:29	LI SO	Long Island Light.
21:12:31	CE PD	Yes, sir, will you take all you can in on the Norwalk tie? We're just about to lose our ties from the north here.
21:12:39	LI SO	We're trying to give you all the help we can.
21:12:41	CE PD	Alright, thank you, pal.
	LI SO	Right.
21:13:02	CE PD	Yes, sir.
21:13:05	GEN STA	Is that voltage for real?
21:13:07	CE PD	Yes, sir, voltage, ah, 5 percent voltage reduction.
21:13:09	GEN STA	OK, right.
21:13:10	CE PD	Right.
21:13:20	AK 2	AK 2, Frisch.
21:13:21	CE PD	Five percent voltage reduction.
21:13:22	AK 2	Five percent. Yes, sir.
21:13:23	CE PD	Right.
	AK 2	Right.
21:13:30	GEN STA	Gen Station.
	CE PD	Yes, 5 percent voltage reduction.
21:13:32	GEN STA	Yeah, OK.
21:13:33	CE PD	Right.
	GEN STA	. . . .
21:13:41	CE PD	Yeah, 5 percent voltage reduction.
21:13:43	GEN STA	Five percent voltage reduction.
21:13:45	CE PD	Right.
21:13:47	GEN STA	OK. What happened, anyway?
21:13:49	CE PD	Lost Indian Point, lost some of the ties.

Time	*Company and position*	*Conversation*
21:13:50	GEN STA	Oh, OK.
	GEN STA	Collins.
21:14:00	CE PD	Yeah, 5 percent voltage reduction.
21:14:01	GEN STA	OK.
21:14:03	CE PD	Right.
	GEN STA	. . . John . . . .
21:14:12	CE PD	Yeah, 5 percent voltage reduction.
21:14:14	AST GTs	Yes, sir.
21:14:15	CE PD	Right.
21:14:21	AST GTs	Kelly, here.
21:14:22	CE PD	Five percent voltage reduction, Kelly.
21:14:24	AST GTs	OK, fine.
21:14:25	CE PD	Right.
	GEN STA	Yeah . . . .
21:14:35	CE PD	Five percent voltage reduction.
21:14:37	GEN STA	OK.
21:14:39	CE PD	Righto.
21:14:49	WAT	Morgan.
	CE PD	Yeah, Morgan, 5 percent voltage reduction.
21:14:53	WAT	We got it, chief, we're down.
21:14:55	CE PD	OK, pal.
21:14:56	WAT	Right. Hey, listen—
	CE PD	Yeah.
21:14:59	WAT	That's 5 percent over existing voltage, which is 13.6, right?
21:15:00	CE PD	Right.
	WAT	OK.
	74TH ST	Seventy-fourth Street.
21:15:10	CE PD	Ah, 5 percent voltage reduction, pal.
21:15:13	74TH ST	OK.
		OK, pal.
21:15:14	CE PD	Yes.
	GEN STA	. . .
21:15:24	CE PD	Yeah, 5 percent voltage reduction.
21:15:25	59TH ST	Yes.
21:15:26	CE PD	OK.
21:15:28	59TH ST	Oh, reduce load, sir?
21:15:29	CE PD	I said 5 percent voltage reduction.
21:15:31	59TH ST	Oh, thank you, 5 percent voltage reduction.
21:15:33	CE PD	Right.
	59TH ST	Alright, thank you.
21:15:55	CE PD	Cockerham, hello. Five percent voltage reduction, pal.
21:15:57	QDO	OK, yeah. Hudson Avenue just notified me. I told them that I was very sure that it was legitimate.
21:16:01	CE PD	Yes, it is.
21:16:02	QDO	OK, look 702—
	CE PD	Yeah.
	QDO	It was cut in at Hudson Avenue East at 21:16.
21.16:11	CE PD	Seven hundred two at 9:16.
	QDO	Right.
	CE PD	Good enough.

Time	*Company and position*	*Conversation*
	QDO	Righto.
	CE PD	Right.
	CE PD	Yes sir, Willie.
21:16:16	NYPP SPD	Did you institute voltage reduction?
21:16:18	CE PD	Yes sir, man, 5 percent.
21:16:20	NYPP SPD	We're not getting much relief on that tie.
	CE PD	I know.
21:16:25	NYPP SPD	I had Long Island go into 5 percent also to try to help you guys, and oh, we got Roseton coming down. I don't know what else I can do for you. If you lose 80 line, you're really gonna be out of business.
21:16:37	CE PD	You're not kidding, man. You're not kidding.
21:16:38	NYPP SPD	Ok, now, if it don't come down, maybe they'd better go to 8 percent then.
	CE PD	OK.
	NYPP SPD	OK.
	CE PD	Right.
	NYPP SPD	Right.
	CE PD	Cockerham.
	CE PD	Cockerham.
21:17:01	CE PD	Cockerham.
21:17:03	PASNY LD	Yeah, okay, now for this 9 o'clock hour . . . .
21:17:05	CE PD	Let me call you back.
21:17:07	PASNY LD	OK.
21:17:08	CE PD	We're busy right now.
	PASNY LD	Sure.
	RAV 3	. . .
21:17:42	CE PD	You any good for any more?
21:17:46	RAV 3	On the vars?
21:17:48	CE PD	On the machine.
21:17:50	RAV 3	On the machine, ah, I don't think so 'cause we could trip.
21:17:51	CE PD	Uh, huh.
	RAV 3	. . . and I don't think you want to do that.
21:17:53	CE PD	No, I don't want you to trip.
21:17:55	CE PD	OK, pal.
21:18:10	CE PD	Cockerham.
21:18:11	AST GTs	Hey, Cockerham, did you lose something else? We just took a big belt.
21:18:13	CE PD	When?
21:18:14	AST GTs	Just now.
21:18:15	CE PD	Just now.
21:18:17	AST GTs	Right, 9:19.
21:18:19	CE PD	9:19, huh?
21:18:21	AST GTs	Right.
21:18:22	CE PD	Alright, we'll look around.
21:18:23	AST GTs	OK.
	CE PD	Right.
21:18:29	AST GTs	Hello.
	CE PD	Yeah.
	AST GTs	Tom King speaking . . . .
	CE PD	Yeah, Tom.

Time	*Company and position*	*Conversation*
	AST GTs	Listen, on number 1 we only can give you 120 MW.
21:18:30	CE PD	Alright.
21:18:36	AST GTs	Everytime we come above it, that bearing starts to get up there at 200 to 210 degrees. We can't handle it.
21:18:42	CE PD	Alright.
21:18:44	AST GTs	We're gonna sit for 120—number 1, now number 4. I just talked to him, and he's gonna try give you 10 more MW's over there for 140 to 150.
21:18:52	CE PD	Anything you can give us, pal.
21:18:53	AST GTs	OK, you ask for help—we're trying to help you out.
	CE PD	Thanks, pal.
	AST GTs	OK, right.
21:18:56	CE PD	Yes, Willie.
21:18:57	NYPP SPD	Yeah, you gotta shed load immediately or you're gonna go right down the pipe with everything. You've lost that 80 line there now.
21:19:02	CE PD	He lost the 80 line?
21:19:04	NYPP SPD	Yeah, you'd better shed load immediately.
21:19:06	CE PD	Oh . . . .
21:19:07	NYPP SPD	At least 600 MW, anyway.
21:19:08	CE PD	Yep, right.
	NYPP SPD	OK.
	CE PD	Right.
21:20:43	CE PD	Cockerham.
21:20:44	NYPP SPD	Hey, John, will you shed load down there immediately?
21:20:46	CE PD	Yeah, right.
21:20:47	NYPP SPD	At least 1,000 MW or you're gonna go right down the pipe.
21:20:50	CE PD	Alright, pal.
21:21:11	CE PD	Cockerham.
	AST GTs	Yeah, Cockerham, we're getting some belts over here.
21:21:13	CE PD	I know you are.
21:21:14	AST GTs	Oh, babe, as long as you know about it.
	CE PD	Right.
21:21:16	CE PD	Cockerham.
	CE PD	Cockerham.
21:21:22	PASNY LD	Yeah, Indian Point 3 says he's running low on outside power. Is there any way . . . ?
21:21:25	CE PD	You better believe he is.
21:21:29	PASNY LD	Yeah, I'm sure you're well aware of that.
	CE PD	Yes, sir.
	PASNY LD	OK, Frank.
	CE PD	Right.
	PASNY LD	Right.
	CE PD	Cockerham.
21:23:02	CE PD	Cockerham.
21:23:04	AST GTs	Cockerham, do you want the gas turbine on numbers 3 and 4?

Time	Company and position	Conversation
21:23:09	CE PD	Ah, hold on 1 second.
21:23:14	CE PD	Ah, no. Alright, bring it in.
21:23:18	AST GTs	Bring it in. Alright, I'll tell him.
	CE PD	Right.
21:23:21	CE PD	Cockerham.
21:23:23	RAV 2	I'm trying not to go no higher than 360 . . . . I got regulator problems. I got one regulator on the Johnson that's stuck.
21:23:30	CE PD	Give me everything you can and—
21:23:32	RAV 2	And on 20, I got 380, and that's as high as I can go there, too.
21:23:35	CE PD	Alright, anything that you can give me I would appreciate.
	RAV 2	OK.
21:24:30	CE PD	Cockerham.
21:24:33	Narrows	Ah, Narrows . . . .
	CE PD	Yes, sir.
	Narrows	OK, we got them on time.
21:24:36	CE PD	I'll tell you what—hold them and I'll get with you, huh?
21:24:38	Narrows	Hold them right where we are?
21:24:40	CE PD	No, no, no. Bring everything you can in, but I'll get the times from you later.
21:24:44	Narrows	OK, I understand.
21:24:46	CE PD	Right.
21:25:48	CE PD	Yes, sir, Bill.
21:25:29	NYPP SPD	Yeah, I'm going to tell you one more time, if you don't shed about 600 MW of load . . . .
21:25:35	CE PD	He's doing it as fast as he can, pal.
21:25:37	NYPP SPD	All you got to do is press a button to get rid of it.
21:25:39	CE PD	That's what he's doing right now.
21:25:41	NYPP SPD	Shed 600 MW immediately or you'll lose that—Linden, and you're out of business.
	CE PD	Yes, I . . . .
	NYPP SPD	That's the only thing you got left, John.
21:25:46	CE PD	I know that.
	NYPP SPD	OK.
	CE PD	Right.
21:26:40	CE PD	Yes, sir.
21:26:44	WDO	Yeah, Jack, what can I say? We got a lot of action, but there is a lot of stuff alive. Backfeed.
21:26:51	CE PD	I know.
21:26:53	WDO	Now, I don't know. I'd like to consult with him, you know, if you want to perhaps start trying to close some of these breakers back in. You know.
21:27:01	CE PD	You mean the 345's?
21:27:03	WDO	Yeah.
21:27:04	CE PD	Ahuh.
21:27:05	WDO	Like, for instance in Millwood West for one—
	CE PD	Right.

Time	*Company and position*	*Conversation*
21:27:09	WDO	Breaker 10 is open there right now. Okay, 16 and 18 are open there, and 98 is dead going over to Buchanan.
21:27:19	CE PD	Right.
21:27:20	WDO	Because it's open at Buchanan on the south bus, too—but 97 now, breaker 10 is open, ah, and we're gathering targets, so we can probably go back with that. I would say. 79/93 combination—we got a whole lot of audiotone targets in Eastview.
	CE PD	Uh, uh.
21:27:43	WDO	And I would say they did a lot of receiving that cleared 1, 2, 4, and 6 in Eastview.
	CE PD	Uh, uh. Oh, oh.
	WDO	But, oh—
21:27:47	CE PD	I think the . . . just hit the fan.
21:27:51	WDO	Oh . . . boy, oh boy. Yeah, we're getting it now. It's opening up everywhere.
21:28:03	CE PD	Yes, yep. Listen, I'll get with you.

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Appendix E

CON EDISON'S HUMAN SUBSYSTEM AND ITS IMPACT ON EVENTS OF JULY 13, 1977[1]

by Joseph G. Colmen, Ph. D.

Electric power systems depend for their total effectiveness, as do many other systems, on a smooth and functional interrelationship between two major subsystems: technological and human. Their symbiotic nature was clearly seen in the electric power failure in New York City on July 13, 1977, when the system experienced a combination of problems, including the malfunction of equipment, insufficient information, poor coordination between facilities, unsatisfactory situation assessment, failure to take required action, and the like. The human aspects may be generalized as reflecting difficulties in assessing causes for the problem; knowledge of the status of the equipment; coordination and communication with interconnected systems; choosing corrective actions; and carrying them out once chosen.

Over the years, the industry has commendably geared up to meet heavier and heavier demands for electricity at lower cost by modernizing plant and equipment and, to a greater or lesser degree, by installing computers to facilitate information flow and decisionmaking processes. Until much more recently, however, comparable emphasis has not appeared to be given to the human element in the system.

The effect of this imbalance has not always surfaced, largely because the human side of the equation is so highly accommodative to changing and increasing demands upon it. When stress is continuous over time or is very extreme even for a brief period, however, performance at the work place can become so impaired that normally effective judgment and behavior give way to directly visible "error."

Just as guarantees cannot be given for the universal performance of technical systems, however fail-safe they may have been constructed to be, behavioral scientists correctly caution that no system can be designed to guarantee that human beings will always perform in accordance with desired expectations, particularly in low-probability situations.

The ways in which the emergency affected the performance of a few individuals is now obvious to most, but the implications of the event went well beyond this handful of personnel and pointed to a clear need for answers to a fundamental and possibly more pervasive question: Were there conditions in the Con Edison system that could have contributed to the human reactions that occurred? And if these conditions existed, how could the system be altered to insure maximally reliable human performance in the future? To address these questions, the components of the behaviorally related subsystem that could have contributed to the enormity of the New York, N.Y., July 1977 power failure have been investigated: recruitment and selection, training, evaluation of performance, human factors vis-a-vis equipment factors, communications, clarity of operating procedures, specification of locus of responsibility, physical and mental health certification, and employee counseling.

The data for the analysis that follows were gleaned in part from existing reports and publications, but the most useful information was derived from person-to-person discussions with Con Edison officials in New York on February 22, 1978[2]. These discussions revealed that the company has generally responded vigorously and creatively in attempting to correct deficiencies in the human subsystem associated with the power failure.

RECRUITMENT

Normally, the larger the pool of applicants from which a selection is to be made, the greater the likelihood of obtaining a superior employee, even

[1]Submitted to the Federal Energy Regulatory Commission on February 24, 1978.

[2]A. N. Terrari, Assistant Vice President for Transmission Operations and Technical Services; Aaron S. Sadoff, Senior Vice President, Employee Relations; Stephen Bram, Manager, System Operations Control Center; Jack Feinstein, Chief System Operator; Margaret A. Regan, Director, Personnel Administration; and Harold Schmitz, Staff Psychologist in Personnel Administration.

without regard to the sophistication of procedures used to make the selection decision. In selecting persons to become system operators, Con Edison may have inadvertently suffered because of the constriction in its applicant pool.

Selection to the six system operator positions has traditionally been made from the pool of only five persons employed as power dispatchers; power dispatchers in turn from some 32 persons employed as district operators; district operators from emergency supervisors; and they from larger numbers of field operators, substation operators, substation mechanics, and others. Because each vacancy was filled only from those available at the next lower level, the probability (as differentiated from the reality in any individual case) of obtaining a superior person decreased.

To remedy this condition, the company intends to open future system operator vacancies and the new position of senior system operator to broader recruitment. In fact, of the eight senior system operator positions being established, well over half will be filled by persons not now in the next lower position in the ladder, power dispatcher. This action should improve the probability of identifying personnel who will perform at high levels of quality.

The relatively rigid promotion ladder used to reach the position of system operator may have also acted to depress the general quality level of recruitment. An assumption is made in such a procedure that performance in positions lower in the ladder is a valid predictor of performance in the higher positions. This would be true if enough of the elements associated with successful performance in one were also present in the other.

In the case of system operator, however, where power dispatchers represented the sole source of candidates, this assumption may not have been warranted. Without detailed analyses of the job tasks and job-referenced qualifications demanded by each of these positions, one can only speculate on the degree of equivalency among them. Yet casual reading of brief statements on the work of the power dispatcher may not unreasonably lead to the conclusion that the major duties and responsibilities of that position are quite different from, and even potentially conflicting with, those of the system operator. The power dispatcher appears to be concerned primarily with the economics of his company's purchase, sale, and use of electric power; the system operator, on the other hand, with the larger picture of interrelationships with other electric power utilities under emergency conditions, with much less regard to the economics within his own company.

If the presumption of difference between power dispatcher work and system operator work is valid, Con Edison may have inappropriately limited itself in filling the latter jobs only with employees in the former. The action being taken by Con Edison to broaden the recruitment base for filling system operator and senior system operator positions, however, serves to reduce the effects of the possible dissimilarity between power dispatcher and system operator positions.

SELECTION

If selection for the position of system operator represents the end of a chain of personnel selection or promotion processes, the "funneling," which starts with entry into the energy supervisor position and continues to the system operator position, should assure inclusion and retention of the qualities essential for ultimate success as a system operator.

These qualities should of course derive from comprehensive psychological analysis of the job tasks, the result being an inventory of qualifications requirements for the job. It would be from such an inventory that existing methods of assessment and reassessment might be identified or new ones produced. It is not altogether clear, as suggested in the discussion on recruitment, that the ladder of positions leading to system operator is interrelated, that they do indeed form a logical cohesive series, or that qualities most highly associated with system operator performance are not "washed out" as persons move upward from rung to rung.

Con Edison's personnel department operations require, for each job in the company, completion of a position guide, which specifies the duties, purpose, and responsibilities of the incumbent. The guide also contains a section that translates the job duties into qualification requirements, which in turn set the foundation for identification of valid selection procedures.

The company has, in addition, through contract with a consulting organization, subjected all nonexempt positions to a form of job and qualification study by a technique known as "threshold trait analysis." Con Edison, with confidence growing out of understanding of its psychometric validity, has for some time projected the extension of that technique to its exempt positions, including system operator, but, as of February 1978, had not yet initiated it.

A second contract undertaken recently, however, does target directly on the system operator position. It consists of a clinical psychological evaluation of all persons believed otherwise to qualify for system operator or the new senior system operator vacancies, using a standard battery of ten psychological instruments intended primarily to measure motivation, interest, logical thinking, potential adaptation to stress, and color vision. These tests were selected on the basis of job task analysis. Together with a psychological interview, the file of data is analyzed and the candidate placed in one of four candidate categories ranging from "outstanding" to "poor." The clinical report is then used in reaching final judgments relative to selection or promotion. Although no formal data on validity of this procedure within Con Edison are currently available, eports on validity in other utilities are said to ubstantiate its value, and plans to follow up candidates selected by this method will, if pursued, later describe its specific validity for the company. For now, company officials comment on the closeness with which many of the contractor's evaluations parallel their own.

A partial gap in qualifications analysis of system operator positions may, however, still exist. This seems to be most evident in relation to translating emergency-related, job-required behavior into more behaviorally specific abilities. Examples might be—

(1) Ability to function at high levels of effectiveness under conditions where time is critical, equipment damage may be severe, and public reproof for erroneous decisions is likely

(2) Capacity to move instantly from a posture of normal attentiveness under routine working conditions to one of intense alertness

(3) Memory for detailed, complex operating procedures when under duress

(4) Leadership skills in coordination with both immediate staff and staff of other utilities and agencies

(5) High degree of self-confidence required to take charge of a deteriorating situation

(6) Capacity to maintain composure under conditions of stress

(7) Ability to aggregate and use quantitative data from various sources and to make correct decisions from them

(8) Ability to properly assess contingencies in unique situations

(9) Knowing when to change course from an earlier decision and flexibility in making that change

Plans are underway in the company to introduce simulation procedures to the training of system operator and related positions. Although there is verbal agreement on the potential of simulated exercises in screening candidates for those jobs, no plan was described at that time for adapting them for selection purposes.

Emotional and mental health examination, with its obvious implication for functioning under stress, is part of the medical examination required annually for system operator and related position incumbents. Because reaction to stress is difficult to reliably assess in an interview, the company uses a procedure that increases the probability that aberrant job behavior will be detected by requiring supervisors to report it on a form returned to the medical division. The examining general physician reviews the information; where he determines that further evaluation is required, he refers the employee for psychiatric or psychological examination.

Two other approaches might be considered for improving assessment of emotional capacity for performing in system operator and allied positions:

(1) Simulation or gaming exercises (already discussed under training), with or without use of computers, could be developed and used. These would have the advantage of being highly job specific and objectively scored.

(2) The "assessment center" approach, which provides for multiple assessments along dimensions designated as critical to successful job performance, could be used. Candidates for a given position are brought together for a day or more during which such techniques as simulation or gaming, written tests, role playing, team exercises, and others may be used. At the end of the period, overall judgments representing the consensus of trained staff (some representing company management, others professional raters) are arrived at. Con Edison uses this approach in executive and management selection, and is studying the possibility of extending it to selection of system operators as well.

The art of selecting people who will withstand stress has not advanced to a point of major precision, and in fact, agreement on a definition of "stress" has not been reached in medicine, psychology, or physiology. Because of its potential importance in selection of persons employed to perform the critical tasks of system operation and related occupations, however, much more intensive study is desirable.

Although Con Edison has properly directed its attention to selection as a means of improving the reliability of its system operation, still more gain can be expected from systematic validation analysis. The small number of persons in its system operator and senior operator positions militates in part against validation procedures using multivariate and regression analyses. Con Edison might overcome this constraint by taking the initiative to invite a cooperative study with other companies, perhaps on a national scale. By increasing sample sizes, such a plan would permit the use of those appropriate and more advanced statistical techniques in judging the validity of a wide variety of selection methods, and the final construction of an optimally valid, yet practical-to-implement set of procedures.

TRAINING

Con Edison has devoted appreciable attention to training for each of the positions in the system operator ladder.

The training for these positions is represented generally by a combination of progressive job experience and more formal specific knowledge or skill training. The training content appears in the main to be germane to the knowledge and skills inherent in the job task duties to be performed, and the mixture of formal and on-the-job training strategies appears appropriate.

Whether or not the training, beginning with emergency supervisor, incorporates a progression from job level to job level in the types of critical decisionmaking abilities required later for successful performance as a system operator is difficult to determine, but according to reports, those involved in the July 1977 emergency may have been skilled in day-to-day operations, but not in the handling of emergency conditions. It is not suggested that the training of energy supervisors, for example, should include the specific types of decisions required or events confronted by a system operator, because by and large, training should be phased to immediacy of use of the skills being taught. On the other hand, more exposure and practice in skills related to emergencies at each job level may provide a firmer general foundation for reacting effectively later to the exigencies and crises of the system operator job.

One strategy for training holds a great deal of promise for adding reality to the process of system operation training. This would come from supplementing the training of incumbents in a job-by-job mode as is currently the procedure, by the training of all members of an operational team together, including power dispatchers, district operators, and other involved employees. The team would also include the newly added senior system operator and chief system operator of the watch. This procedure would assist in developing skill in the critical aspects of team coordination and interaction and instill clear knowledge of the responsibilities of each. Training of the teams could take advantage of carefully fashioned "laboratory" exercises, with or without availability of computerized simulation facilities.

Of course, as job restructuring occurs, as with the introduction by Con Edison of a chief system operator on each of three shifts (as opposed to one shift previously) and the senior system operator, training programs must be analyzed for their continued relevance and adjusted as necessary.

Evaluation of trainees during the training or through followup of their performance on the job seems largely to be taken for granted. Of course, a large share of the training is conducted on the job, where a supervisor is in a one-to-one instructor relationship with the trainee. In these instances, evaluation of performance is continuous and necessarily informal. Furthermore, the supervisor gets quick feedback on the trainee's skill and knowledge development and can individualize his own responsive planning accordingly. On the other hand, when training is organized more formally, such as that requiring classroom or "laboratory" work, such immediate feedback, except for periodic examinations in the energy supervisor curriculum, is not readily available. Yet it is crucial to know how well trainees perform on the job itself in relation to that training. If trainees in general fail to perform well in one or more parts of the program after training, questions may be raised about the efficacy of the training itself and the need for change. But if only one or a few do not perform well, it may be a reflection of their own inadequacies. For these reasons, the company may benefit from analysis and development of the types of measures (tests, observer ratings, or the like) that can produce evidence of the degree and kind of trainee achievement that has been produced, by trainee and by each program group of trainees. These, in turn, may be used as measures to be correlated with measures of job performance as a basis of program evaluation.

The Con Edison performance appraisal process, described later, requires supervisors to show, when employee performance is below a prescribed level, the nature of training or other activities required as a means of increasing skills. This appraisal may have use, with some adaptation, as a criterion or "success measure," against which trainee performance and training programs may be evaluated.

Although Con Edison's manual for selection and training of system operators presents rather formalized curricula for the classroom training for most positions, it is far less precise with respect to the on-the-job training phases. To insure that the trainee's observations, practice, and skill development closely parallel the critical tasks in the job and that they are successfully accomplished, a detailed curriculum for on-the-job training would be a valuable adjunct. It would serve as a checkoff for the trainee, so that he knows *at each point* where he is, what is expected of him, and how his performance as a trainee will be evaluated. It will also serve to guide the supervisor or instructor so that all trainees receive full coverage of all topics.

To provide greater emphasis in training to the more subtle qualities that appear to be associated with success in system operation, both on-the-job and formal training programs could benefit from inclusion of materials on leadership, decisionmaking, crisis management, command and control, and stress-coping skills under emergency conditions to develop individuals for effective performance as they move up to system operator positions. It is understood that Con Edison is planning to develop and introduce simulations that may encourage development of these and other skills, a development with considerable potential and useful with adaptation for all positions in the ladder.

PERFORMANCE EVALUATION

All employees of Con Edison are given annual appraisals by their supervisors. Based on the position guide, which states the major tasks and responsibilities of each job, the supervisor judges how well the employee met them during the previous year, on a scale with three positions: D (did not meet satisfactorily); M (met satisfactorily); and E (exceeded expectation) From the separate ratings, the supervisor provides ar overall rating on a five-point scale, from excellent to unsatisfactory. Recommendations for improvement in the forthcoming year are made by the supervisor.

As with most organizational rating systems, distribution of employee ratings has tended to skew toward the high end of the scale, probably because objective assessments suffer from social constraints. If Con Edison will be developing simulation exercises for use in training, the same instrumentation may offer a standardized and objective basis for judging job performance in system operation positions, thereby serving as a valuable supplement to the performance appraisal process.

Evaluation of performance in a currently held position is usually required as one criterion of selection for a new, higher level position. The performance appraisal provides a basis for recording such information systematically. Although the performance appraisal provides a basis for judging some qualities that may be critical to success as a system operator, it may not at present insure that *all* necessary qualities are incorporated for all jobs in the system operator ladder. The list of emergency-related, job-required behavior presented in the section on selection may suggest the scope and depth to be sought. In addition to providing an assessment of these abilities, supervisors might be encouraged to cite incidents of highly positive or negative performances that support their assessment rating. These can later be incorporated in the performance appraisal form as an addendum for system operator positions.

PERSON-MACHINE RELATIONSHIPS

Although Con Edison recognized that machines and employees interface in important ways in its electric power utility system, events of July 13, 1977, suggested the need for reevaluation of that interrelationship. The consequences of human factors gaps were reflected in the following incidents:

(1) Essential information appeared on displays in unnecessarily fragmented form, hindering smooth, immediate integration of all data needed for speedy decisionmaking. Problems of inaccuracy and delay in effecting action resulted. Con Edison recognizes these deficiencies and is studying how best to restructure and relocate displays, both in present and next generation of control room equipment. Also being studied is a capability for automatic computerized calculation of numerous alternative decisions open to the operator at any point in time, which if implemented could reduce potential for human error, increase speed of decisionmaking, and optimize decision choice.

(2) Demands on the system operator for numerous successive actions in "shedding load" at each station were both time consuming and nerve wracking, causing position-switching errors in the process. In recognition of this problem, Con Edison has already modified present display and decision-implementation equipment to reduce some of these effects. In one instance, for example, the system operator who, during the failure, had to activate some 30 different keys to "shed load," will in future circumstances have to activate only three.

(3) Installation of automatic overcurrent protective devices on all facilities is under consideration by the company to eliminate the danger of delayed human operator response in taking lines out of service.

Systematic analysis of all man-machine interfaces in the electric power system is integral to the projected control room equipment replacement. Because delivery is still several years away, however, the same depth of analysis may be needed for the present equipment, and all practical modifications made in it so that (1) unnecessary demands on the human operation during emergencies can be minimized, and (2) the human operator can be provided with better organized and aggregated data to facilitate accurate and timely decisionmaking.

COMMUNICATIONS

Problems in communication that appeared during the power failure were exemplified by the use of imprecise terminology between pool members, creating confusion as to the nature and dimensions of the emergency, and resulting in delays in making effective response. A comprehensive analysis of all communication links, strategies, and modalities used between human members of the system could lead to recommendations for reducing the dangers of inadequate communication during emergency conditions. One effective model is seen in oral communications between pilots and air traffic controllers, where, for example, a prescribed lexicon, psycholinguistically free of ambiguity of interpretation, is used for alphabet designations (e.g., alpha for A) and for reporting specific conditions or actions. Con Edison has expressed concern about the problems of communication, but sees that the problems go beyond the company to the power pools and other utilities in the State of New York and in the Northeast generally. Given the volume of communication outside Con Edison's territory, this position is probably justified. Action to initiate a consortium effort along these lines requires early implementation.

APPLICATION OF OPERATING PROCEDURES

Con Edison system operators and their associated colleagues operate under sets of prescribed, written regulations or procedures, some issued by the company, others by the New York Power Pool or other agencies. These are kept current as new procedures are developed. Operating procedures are covered in appropriate training programs, and when new releases are published, each operator must sign a statement that he has read and is familiar with them.

In spite of these precautions, procedural "errors" contributed to the power failure. For example—

(1) Lack of strict adherence to New York Power Pool Operating Reserve Policy (OP-2-7) in the time period before the power failure

(2) Failure to use available control facilities

(3) During restoration, departures from the plan, which were believed to have created delay in full restoration

There is a belief that experience as an operator leads to almost unconscious application of procedures, but this argument may be weak because (1) reading and signing a regulation offer no assurance that it has been properly comprehended; (2) memory suffers, particularly for little-used operating procedures, such as the critical ones that apply only in emergencies; and (3) the language used in the regulation itself may be ambiguous, thereby conveying unintentionally different instructions to different readers. A complete review of all operating procedures, now and periodically, would be essential to produce modifications to insure (1) their currency under present or changed conditions; (2) their freedom from ambiguity of interpretation by various members of the system. In addition, employees should be tested periodically for knowledge of the procedures. To accomplish this, a series of tests might be constructed and administered; when employees scored below a specified acceptable level, or failed a particularly critical item, training and retesting might be required.

LOCUS OF RESPONSIBILITY AND COORDINATION

Confusion in responsibility for action appeared at different points in the events of July 13, 1977. One of these was evidenced by apparent ignoring of a repeated request by the senior pool dispatcher to the system operator to shed load to protect the integrity of the system. In another instance, the watch system operator consulted with the chief system operator before taking corrective action.

Several actions have already been taken by Con Edison to establish definitive lines of authority and delineate responsibility. With creation of the senior system operator position, command and control are vested there. Capable of standing back to assess the total situation in an emergency, the senior system operator can override the system operator's decision, or indeed take over control entirely. By reducing workload on the system operator and clarifying the ultimate authority, problems of locus of responsibility should be greatly reduced in future power failures.

In another vein, problems of coordination among planning, maintenance, and operating staffs seem to have compounded already difficult problems. One example of the consequences of weak coordination was the absence of a required report to system operations that maintenance was underway on certain combustion-turbine units, a factor of importance in deciding upon action to be taken.

A comprehensive review of coordinative mechanisms among the principal components of the system would help to uncover this type of problem and pinpoint responsibility for the future.

The goal would be a unified command, with all team members, inside and out of the system operator's control, totally cognizant of their roles and responsibilities and ready to take cohesive action under emergency conditions.

EMPLOYEE COUNSELING

Other than for problems related to alcoholism, Con Edison does not offer a counseling service to employees. Such a service, conducted on a voluntary, confidential basis, may offer a way to reduce distractions of personal or work-induced psychological burdens on system operators and others in that ladder, thereby freeing them to concentrate on the crucial decisions they must make, particularly under emergency conditions. The concept of "shedding load" has analogous application to the human system as well as to the power system.

CONCLUSIONS

It is not possible to conclude from the data at hand that the Con Edison system, as it existed on July 13, 1977, made such unreasonably extreme demands that appropriate response was totally beyond a system operator's capability to perform. On the other hand, had numerous improvements in equipment and personnel and training practices been implemented before that date, it is probable that the burden of the emergency on the operator would have been diminished.

An underlying factor evident from investigation of the multiple facets of the system was the apparent insufficiency of emphasis on the effects of emergency conditions, with their associated stress, on human performance. The changes instituted by the company since last year move in the right direction, but as suggested by the recommendations made in this section, do not as yet fully take advantage of the state-of-the-art in human engineering, psychometrics, or personnel and organization research.

The extent to which the changes made or recommended will upgrade system performance in future emergencies, however, is not possible to calculate without a number of prior analyses. To estimate improvement would require first, reliable estimates of present quality of performance, assessed against precise criteria, both of equipment and human operation. If performance quality were found to be quite high already, the amount of possible improvement that could be expected would of course be correspondingly small. In this case, some type of cost-benefit analysis would be required to determine whether or not the anticipated gains could be justified by the cost. Second, a plan for application of proposed new practices on experimental terms, along with a design for measurement and analysis of results, would be needed to provide an estimate of the level of actual achievement obtained.

Development and introduction of a national licensing examination for system operators, analogous to that used with nuclear plant operators, has been suggested by some observers as a means of building greater safeguards for reliability into the system. It would be our opinion that, given the reported variability among electric power systems nationally, and the consequent need for variability of response to meet individual conditions, a Federal examination pegged to the presumably limited commonalities among systems would yield insufficient gains to justify cost or this level of Federal involvement. More value, we believe, could come from a Federal interest displayed through regulatory standards, requirement for company reporting, and audit in the behavioral and personnel fields. This would serve to encourage companies to elevate these practices on their own; the result could be a more creative and responsive level of research and development that, in the long run, might be more productive of the level of system reliability everyone, including the companies, desires.

SUMMARY

Analysis of the human subsystem of Con Edison's power system substantiates that the company has sharply increased its attention to the behavioral side of its operation. Although a number of plans for improvement were under consideration before the power failure of July 13, 1977, a number of changes in recruitment, selection, human engineering, job restructuring, and locus of responsibility in system operation have been made since that time. These should go a long way toward increasing reliability in a system where tolerances for error are low. Additional gains may also be anticipated from the company's next generation of control room equipment, which will benefit from the application of human factors knowledge to displays, switches, data aggregation methods, and operations research application of logic decision models.

Suggestions have been made for additional actions that have potential for incremental improvement in human performance as system operators, particularly in connection with the need to function at top efficiency under conditions of emergency. To a large extent, they extend advances already made in selection, training, and performance appraisal, and suggest other actions that relate to communications, operating procedures, and employee counseling.

THE HUMAN SUBSYSTEM: SUMMARY OF RECOMMENDATIONS

(1) Qualifications requirements for system operator and allied positions should be supplemented by greater elaboration of emergency-related behavior. For example, "capacity to move instantly from a posture of normal attentiveness under routine working conditions to one of intense alertness" or "knowing when to change course from an earlier decision and flexibility in making that change."

(2) If simulation procedures are being developed for use in training, they should be adapted for use in selection and performance appraisal as well.

(3) A study to validate selection procedures for system operator should be undertaken by a consortium of electric utilities, so that samples of sufficient size for appropriate experimental design and statistical methodology can be obtained.

(4) More emphasis should be given to evaluation of training of system operators and other operating personnel in related positions, both during the training and afterward, on the job.

(5) Curricula for the on-the-job phases of training should be developed as a basis for standardizing objectives, content, and methodology.

(6) Training for all positions in the system operator ladder should tend to develop skills in decisionmaking, stress-coping, command and control, leadership, and crisis management.

(7) Opportunities should be constructed for training together all members who work as a systems operations team as a means of elevating the total staff effort, particularly under emergency operating conditions.

(8) The performance appraisal system should be expanded for system operator employees to assess in greater depth employee performance of emergency-related behavior.

(9) Comprehensive analysis and modification of all present man-machine interfaces, as needed, should be undertaken to determine where unnecessary or overcomplicated demands that could be assumed by machines are now imposed on system operators, and where it is possible to provide the operator with better organized and aggregated data to facilitate accurate and timely decisionmaking.

(10) Ways to remove ambiguity in oral communication between pool members, other involved agencies, or both should be investigated and implemented.

(11) Operating procedures should be reviewed to insure their currency under changed procedures and to remove any ambiguity that may be present.

(12) Employees should be examined periodically on their knowledge of the operating procedures, particular-

ly those that apply under emergency conditions. Written tests might be constructed for this purpose.

(13) Use of an "assessment center" approach should be evaluated as a basis for selection of candidates for promotion to system operator positions.

(14) A voluntary, confidential employee counseling service should be made available to system operators to assist them in coping with personal or work problems that may affect their decisionmaking judgment on the job.

Appendix F

LIGHTNING PROTECTION FOR TRANSMISSION LINES

The initiating cause of the July 13 power failure was a series of lightning strokes, which over a period of less than ½ hour resulted in outages of four 345-kV transmission circuits. A similar, and perhaps even more serious, series of strokes occurred on the Con Edison system less than 3 months later and required prompt action, including the shedding of 325 MW of customer load to prevent a recurrence of the July 13 incident. It is, therefore, important to review the adequacy of the manner in which the Con Edison system seeks to shield its high-voltage transmission system from such occurrences and to consider whether further steps need to be taken.

In general, transmission-line design includes the design of appropriate terminal (substation) facilities, such as circuit breakers, lightning or surge arresters, protective relay equipment, and transformers. This discussion considers only the overhead-line portion between the terminals, where the line is exposed to the direct effect of lightning.

The overhead-line structures must have sufficient electrical insulation (insulators in combination with airgaps) to withstand a combination of voltage stresses. Among the sources of these are lightning, switching surges, and power frequency voltage stresses. These various voltages stress the line insulation in different ways so that a balanced insulation design is needed. The highest voltage magnitudes and most rapid rates of voltage rise are produced by lightning.

Both the frequency of occurrence and the effect of lightning strokes on transmission lines are functions of a number of variables. Geographic location determines the expected degree of thunderstorm activity, often expressed as the isokeraunic level, or mean annual number of days on which thunderstorms occurred. Tower design variables include height, airgap, insulator string length, and the degree of shielding afforded by ground wires. Tower resistance to electrical ground is a function of footing design, local soil resistivity, and the extent of counterpoise, or conductors connected to the footings to reduce resistance to ground. Local mean wind velocity may also be important. Studies have shown that shielding failures[1] predominate when line structures are high and shielding angles[2] are large and accompanied by low structure footing impedances to ground; back-flashover[3] events are most prevalent when structure footing impedances are high in association with low levels of conductor insulation and low line structures. Line design evaluations have also shown that for an incremental increase in designed transmission-line availability (stated in terms of probability of unavailability), there is a greater incremental increase in cost associated with improved lightning performance than for parallel improvements in the power frequency performance or the switching surge performance of the line. For extra-high-voltage (EHV) transmission (greater than 230 kV and less than 800 kV), a substantial number of the line lightning strokes will not cause flashover, because the line insulation can withstand the voltage generated by strokes of moderate severity.

Lightning performance of transmission lines is measured in tripouts per 100 line miles per year. EHV lines may be designed to achieve tripout rates approaching 0.5 tripouts per 100 line miles per year, though it does not appear possible to design a "lightning proof" line. Lightning flashovers, however, are generally momentary, and high-speed reclosing at line terminals may provide consistent line availability.

In 1967, the Institute of Electrical and Electronics Engineers (IEEE), published a report on EHV line outages covering the period from January 1950 to December 31, 1964.[4] In the 345- to 360-kV transmission-line class, 3,522 miles of line, involving 51 circuits and 14,743 mile-years, were included in the study. The report showed that 64.4 percent of the line outages were associated with lightning phenomena, giving a performance index of 3.04 tripouts per 100 miles per year, as

[1]A shielding failure is an occurrence in which a lightning stroke bypasses the overhead ground wire and terminates on the phase conductor.

[2]The shielding angle is the angle between the vertical line through the overhead ground wire and a line connecting the overhead ground wire with the shielded conductor.

[3]A back flashover is a flashover of insulation (airgap or insulator string) resulting from a lightning stroke to part of a network or electric installation that is normally at ground or lesser potential.

[4]Members of the IEEE Working Group on EHV Line Outages of the General Systems Subcommittee, Transmission and Distribution Committee, and Edison Electric Institute Working Group on EHV Line Outages, Transmission and Distribution Committee, "Extra High Voltage Line Outages," *IEEE Trans. Power Appar. Syst.*, vol. PAS-86, No. 5, May 1967, pp. 547–562.

compared with an index of 4.72 for all causes. Of the lightning outages, 86.6 percent were temporary outages, and 13.2 percent were permanent outages. All terminal-equipment failures, however, were permanent outages. With regard to temporary outages caused by lightning on circuits with automatic reclosing (37 out of a total of 51 circuits), automatic reclosing was successful in 340 (96.1 percent) of the 354 events in which high-speed reclosing was used and in all four reported situations in which slow-speed reclosing was used. In 23 (5.1 percent) out of 448 occurrences, lightning outages caused loss of customer load.

The report surveyed seven 345- to 360-kV circuits, involving 385 miles and 987 mile-years operating with isokeraunic levels of 30 to 39, which is similar to the level for most of the overhead 345-kV lines of the Coı Edison system. No lightning outages were reported fo 345- to 360-kV transmission-line configurations with isokeraunic levels of 30 to 39 or lower.

The July 13, 1977, disturbance on the Con Edison system was initiated by the tripout of the Buchanan South to Millwood West (W97 and W98) 345-kV lines when phase B of both circuits had lighntning-induced line-to-ground flashovers at 8:37 p.m. The towers for this line also support two 138-kV lines. At 8:56 p.m., a second lightning-induced double-circuit flashover oc-

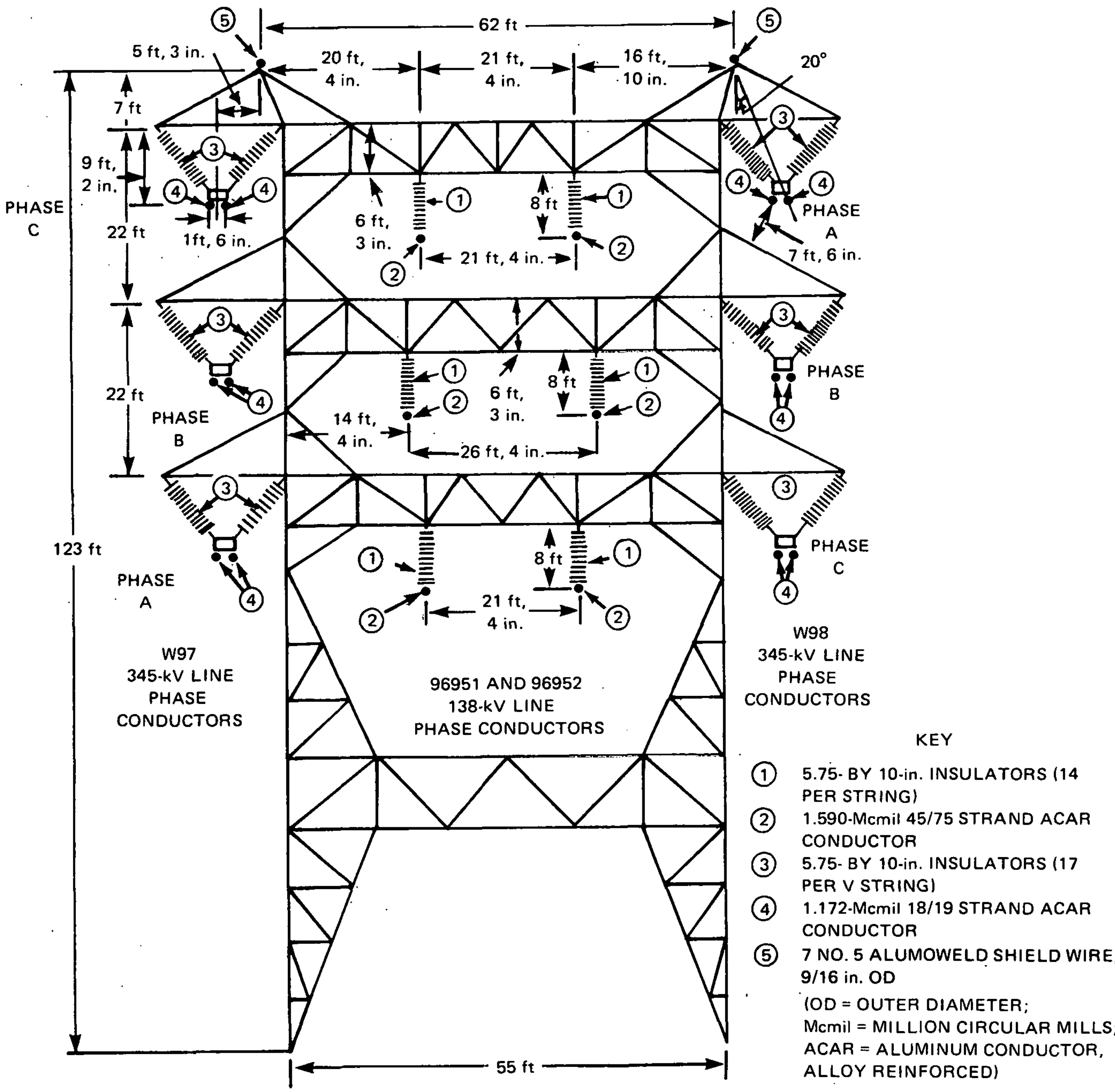


Figure F-1.–Typical four-circuit portal tower, Buchanan South to Millwood West (W97 and W98) 345-kV lines and Buchanan South to Millwood East (96951 and 96952) 138-kV lines.

curred on the C phases of the Buchanan North to Sprain Brook (W93/W79) and Millwood West to Sprain Brook (W99/W64) 345-kV lines, which share double-circuit towers between Millwood West and Sprain Brook.

Con Edison supplied lightning-outage data for its 345-kV lines, covering 3,200 circuit-mile-years for the period before July 13, 1977. For all Con Edison overhead 345-kV transmission lines, an outage rate of 0.75 per 100 circuit-miles per year resulted from 20 single-circuit and 2 double-circuit outages per 100 circuit-miles per year, including one in 1975 on the double-circuit tower line shared by the W93/W79 and W99/W64 345-kV lines between Millwood West and Sprain Brook. Based upon the data supplied by Con Edison, the following line outage rates were calculated for the lines involved in the July 13, 1977, disturbance:

Double-circuit 345-kV line	*Outages per 100 line-miles per year*
Buchanan South to Millwood West (W97/W98)	1.77
Buchanan North to Sprain Brook (W93/W79) and Millwood West to Sprain Brook (W99/W64)	3.38

The IEEE publication on EHV line outages found 0.136 outages per 100 miles per year were double line-to-ground faults with 18 (4 percent) out of 448 associated with lightning for the 345- to 360-kV line voltage class. Of these, 60 percent caused temporary outages, and 40 percent resulted in permanent outages.

Although the lightning-performance characteristics of transmission lines have been studied extensively, most methods of evaluation are approximations using available statistical data because of the many variables associated with lightning phenomena. The major problem in calculating the lightning performance of transmission lines may be directly traced to the extreme difficulty in assembling adequate statistical data necessary for reliable calculations. One recent method is formulated in a publication of the Electric Power Research Institute.[5] This method was used to evaluate probable lightning-performance characteristics for two Con Edison system double-circuit 345-kV lines that had lightning outages on July 13, 1977.

As mentioned earlier, the isokeraunic level for the area in which a line operates is an important variable affecting the lightning performance of the transmission line. The National Weather Service publishes statistics on thunderstorms in the United States. Given in these statistics is the mean number of thunderstorm days, i.e., days on which thunder is heard, per year, by area. One such data source,[6] which gives the thunderstorm statistics for the New York City area for 68 years, gives this isokeraunic level for New York as 31 days per year. This value was used in the calculation.

The tower footing resistances that were used were the average of values along the line, provided by Con Edison, and several higher values to reflect drier-than-normal soil conditions that may have prevailed because of the lack of rainfall in 1977. Figures F-1 and F-2 depict the tower configurations, including the locations of phases A, B, and C of each circuit and the conductor insulation. Tables F-1 and F-2 give the calculated outage rates for the two lines. Other pertinent characteristics of the Buchanan South to Millwood West W97 and W98 double-circuit line are—

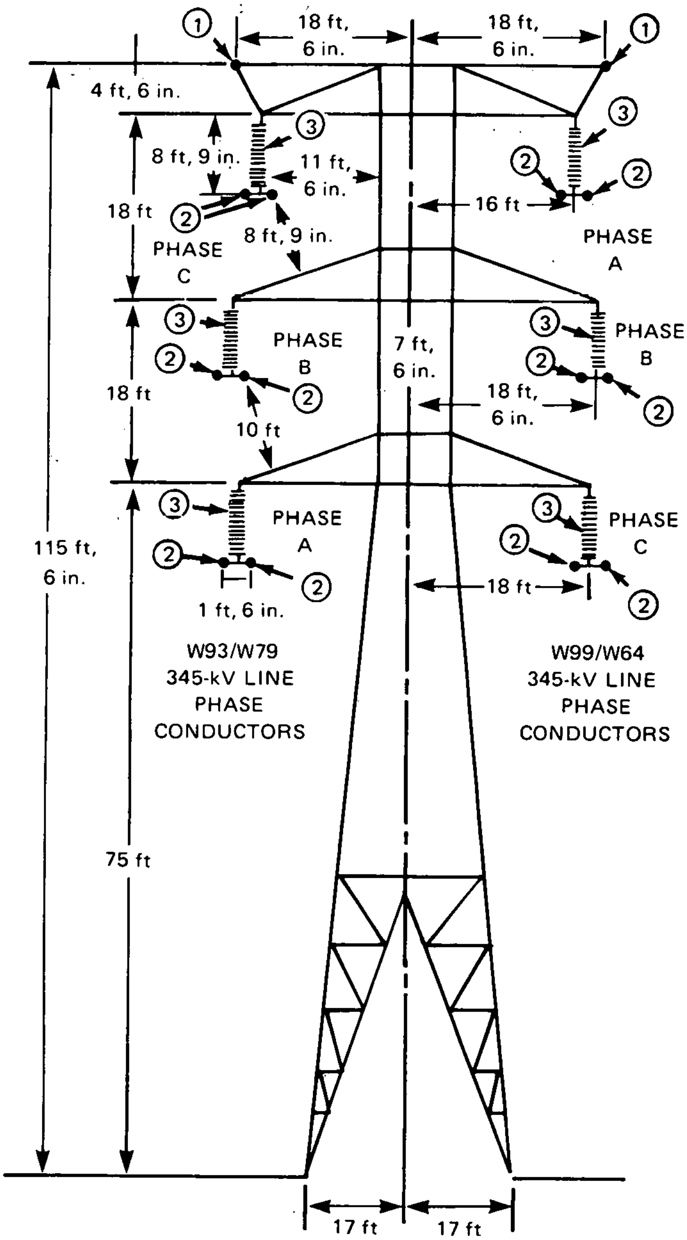
Parameter	*Value*
Isokeraunic level (mean number of thunderstorm days per year)	31
Lightning striking intensity (strokes to earth per square mile per year)	12.4
Rate of lightning striking line (strokes per 100 miles per year)	117.35
Rate of lightning striking tower (strokes per 100 miles per year)	49.46
Tower characteristics:	
Average span length (feet)	932
Sag (feet):	
Conductor	33.8
Ground wire	20.3

Corresponding characteristics of the double circuit line with the Buchanan North to Sprain Brook W93/W79 line and the Millwood West to Sprain Brook W99/W64 line are—

Parameter	*Value*
Isokeraunic level (mean number of thunderstorm days per year)	31
Lightning striking intensity (strokes to earth per square mile per year)	12.4
Rate of lightning striking line (strokes per 100 miles per year)	92.08
Rate of lightning striking tower (strokes per 100 miles per year)	5.34
Tower characteristics:	
Average span length (feet)	773
Sag (feet):	
Conductor	27.8
Ground wire	11.6

[5] J. G. Anderson, "Lightning Performance of EHV-UHV Lines," ch. 12 in *Transmission Line Reference Book, 345 kV and Above*, Electric Power Research Institute, Palo Alto, 1975.

[6] Department of Commerce, Weather Bureau (now National Oceanic and Atmospheric Administration, National Weather Service), *Mean Number of Thunderstorm Days in the United States*, Technical Paper No. 19, Sept. 1952.



KEY

1. 7 NO. 5 ALUMOWELD SHIELD WIRE, 9/16 in. OD
2. 2.493 Mcmil 54/37 STRAND ACAR CONDUCTORS, 1.821 in. OD
3. 5.75- BY 10-in. INSULATORS (15 PER STRING)

(OD = OUTER DIAMETER; Mcmil = MILLION CIRCULAR MILLS; ACAR = ALUMINUM CONDUCTOR, ALLOY REINFORCED)

Figure F-2.–Typical double-circuit tower, Buchanan North to Sprain Brook (W93/W79) and Millwood West to Sprain Brook (W99/W64) 345-kV lines.

The back-flashover outage rates are those obtained for the lowest tower conductors, which were determined to have the greatest probability of back flashover.

Table F-3 shows the experienced and calculated outage rates due to lightning-associated outages for the two double-circuit 345-kV lines.

As shown in table F-3, calculated lightning-associated outage rates approach experienced outage rates for higher values of average footing resistance. Tower footing resistance is a function of the soil characteristics in the vicinity of the tower. The resistivity of earth may vary over wide limits, depending upon the soil composition and its moisture. Swampy ground may have a resistivity of 10 to 100 Ω·m, but dry earth may have a value approaching 1,000 Ω·m, 10 to 100 times higher. Therefore, transmission towers in swampland or moisture-bearing soil usually have low footing resistances, but towers in rocky soil have high resistances.

Con Edison's transmission towers are designed to have a footing resistance of 10 Ω or less. The measured footing resistance value is obtained before the installation of overhead conductors and shielding wires. Several grounding arrangements are used, depending on the initially measured tower footing resistance of each

Table F-1.–*Calculated Outage Rates*[1] *for Buchanan South to Millwood West W97 and W98 345-kV Double-Circuit Line*

Average footing resistance (Ω)	Outage rates (outages per 100 miles per year).		
	Shielding failure	Back flashover	Total
[2]7.6	0.82	0.00	0.82
10.0	.85	.00	.85
20.0	1.77	.04	1.81
30.0	3.98	.14	4.12
50.0	5.95	.77	6.72
100.0	16.31	5.28	21.59

[1] J. G. Anderson, "Lightning Performance of EHV-UHV Lines," ch. 12 in *Transmission Line Reference Book, 345 kV and Above*, Electric Power Research Institute, Palo Alto, 1975.
[2] Value measured when line was constructed.

Table F-2.–*Calculated Outage Rates*[1] *for Double-Circuit 345-kV Line With Buchanan North to Sprain Brook W93/W79 and Millwood West to Spring Brook W99/W64 Lines*

Average footing resistance (Ω)	Outage rates (outages per 100 miles per year)		
	Shielding failure	Back flashover	Total
[2]10	0.96	.0	0.96
20	2.31	.04	2.35
30	5.08	.18	5.26
50	13.08	.77	13.85
100	19.78	4.59	24.37

[1] J. G. Anderson, "Lightning Performance in EHV-UHV Lines," ch. 12 in *Transmission Line Reference Book, 345 kV and Above*, Electric Power Research Institute, Palo Alto, 1975.
[2] Design value for line.

Table F-3.—*Experienced and Calculated Line Outage Rates for 2 Double-Circuit Lines*

Line and type of rate	Average footing resistance	Line outage rate (outages per 100 miles per year)
W97/W98:		
Experienced	–	1.77
Calculated	[1] 7.6	.82
	10.0	.85
	20.0	1.81
	30.0	4.12
W93/W79 and W99/W64:		
Experienced	–	3.38
Calculated	[2] 10.0	.96
	20.0	2.35
	30.0	5.26

[1] Value measured when line was constructed.
[2] Design value.

tower. If a footing resistance of 10 Ω or less at each tower location cannot be obtained with use of ground rods in the vicinity of the tower or extensions of counterpoise longitudinally from the tower, continuous counterpoise to adjacent line towers is used to establish parallel paths for surge current.

As shown in tables F-1 and F-2, the greater portion of the calculated line outage rate results from the shielding failure evaluation. In each, doubling the average tower footing resistance approximately doubles the outage rate. A more pronounced effect occurs in the back-flashover outage rate. Therefore, because the lines are existing tower lines important to the interconnected operation of the Con Edison system, and because extensive line outages would degrade the daily system operating reliability, reexamination of footing resistances would appear to be a more productive avenue of possible improvement with regard to the lightning outage rates of these two double-circuit 345-kV lines than considering changes in the tower structures. Footing resistances higher than previously measured and than tolerable may arise through damage or theft of existing tower footing grounding material. It is recommended that the footing resistances on existing overhead 345-kV lines be examined to verify that existing values are satisfactory.

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Appendix G

EVALUATION OF RELAY OPERATIONS DURING THE JULY 13, 1977, DISTURBANCE

The objective of protective relaying application in electric power systems is to detect faulted or overloaded transmission lines, other electrical facilities, or other power-system operating conditions of an abnormal or dangerous nature; to initiate appropriate control circuit action to prevent or minimize damage to system components, i.e., generators, transmission lines, and associated equipment; and to lessen the impact on the rest of the system. The relay application problem is to select a methodology—a system of relays or relay scheme—for recognizing undesirable situations and for activating appropriate system elements so that the required function is accomplished. Protective relaying application is often described as both a science and an art.

In the Con Edison system, protection of overhead 345-kV transmission lines consists of a primary protective relaying scheme and a backup protective[1] relaying scheme, wherein each functions independently. Each relay system is supplied from different current transformers and station batteries, and when an activating system condition occurs, separate trip coils on associated circuit breakers are energized.[2] The primary relay scheme may use either solid-state or electromechanical relays in a directional comparison power-line carrier-channel relaying system,[3] to provide instantaneous tripping of the protected line section. The backup protection may consist of solid-state or electromechanical relays in a step-distance relaying system with or without a power-line carrier-channel system. Approximately 50 percent of Con Edison's backup protective relay systems use power-line carrier-channel tripping to provide instantaneous, 3- to 4-cycle (0.05- to 0.067-second) clearing for the total line section.

The operation of either primary or backup relays initiates a timing relay to provide backup protection for the line segment, should a circuit breaker fail to open or be slow in clearing a fault. When this timing relay completes its cycle (times out), it will cause the tripping and lockout[4] of other circuit breakers on the same bus and send a signal causing the trip and lockout of circuit breakers in the remote switchyard. The satisfactory opening of the line circuit breaker associated with the breaker-failure relay will deactivate the breaker-failure-scheme timer before it completes its cycle.

All Con Edison system overhead transmission-line terminals are equipped with a single-shot reclosing,[5] which is initiated following a primary carrier-channel trip operation. Tripping activated by any other relays, e.g., backup or breaker-failure relays, will not initiate automatic reclosing. The primary relaying system includes an out-of-step blocking relay to prevent reclosure of a circuit breaker during a system swing (out-of-step) condition.

A detailed evaluation of the protective system operation during the July 13, 1977, disturbance follows.

At 8:37:17 (hour:minute:second) p.m. on July 13, 1977, a lightning stroke to a double-circuit tower on the Buchanan South to Millwood West (W97 and W98) 345-kV line resulted in phase-B-to-ground faults on both circuits. The fault on each circuit was cleared at both line terminals, Buchanan South and Millwood West, in 3 to 4 cycles (0.05 to 0.067 second) by the primary (first-line) system of protection. Therefore, automatic reclosing should have been activated at all four line terminals. The only circuit breaker that reclosed was the Millwood West circuit breaker No. 12,

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[1]Backup protection is a form of protection that operates independently of specified components in the primary protective system and that is intended to operate if the primary protection fails or is temporarily out of service.

[2]A circuit breaker is a mechanical switching device capable of making, carrying, and breaking electric currents under normal circuit conditions and making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short-circuits or faults.

[3]A directional comparison relay system is a set of directional-sensing relays at each terminal of the line that determine if a fault is inside or outside the protected line section. Tripping occurs if the fault sensed is in the direction of the opposite terminal of the protected line section.

[4]A lockout relay is an electrically reset or hand-reset auxiliary relay with the function of holding associated devices inoperable until it is reset.

[5]After the circuit breaker's trip, with or without a delay, the breaker automatically recloses and remains closed if the fault is no longer present.

on the W97 line. Following this incident, all circuit breakers at the Buchanan South Substation were open and locked out by protective relays along with the line circuit breakers at the Ladentown Substation on the Y88, 345-kV line to Buchanan South. Subsequent investigation revealed that Y88 line circuit breakers at Ladentown tripped and locked out as a result of a transfer-trip signal sent from the Buchanan South Substation.

The signal from Buchanan South to Ladentown indicated that the Buchanan South circuit breaker No. 6 had not opened. This relay-scheme malfunction was the result of an improperly designed breaker-failure system. The breaker-failure scheme consisted of a timer relay used to trip backup circuit breakers locally, at Buchanan South, and to transmit a transfer-trip signal to the remote line terminal, Ladentown, should a breaker either fail to open or be slow in opening. Tests on the breaker-failure system indicated that circuit breaker No. 6, along with each individual relay scheme component, operated as designed. However, the overall operating time for the auxiliary relays[6] that indicate whether the circuit breakers are open or closed was greater than the setting for the timer relay that transmits the transfer-trip signal to the remote line terminal. This emphasizes the importance of performing a total relay-scheme acceptance test to determine the adequacy of a new or modified control scheme. It would also appear appropriate that in this case and all others when there is breaker-failure indication the remote line terminal should not reclose into the failed breaker line, as occurred when the Millwood West circuit breaker No. 12 reclosed the W97, 345-kV line.

The breaker-failure scheme is designed such that a substation operator must visit the remote substation, if unattended, to reset the lockout relay to reclose the remote line circuit breaker after a breaker-failure relay-scheme operation. To save time in reestablishing system facilities, it appears that an operator at the substation with the failed breaker should be able to assess the damage and isolate any failed equipment and then to reset the remote lockout relay electrically and close the remote circuit breaker. He should be in a better position to assess the situation than a substation operator at the remote substation. Furthermore, if a circuit breaker fails to open, a signal should be transmitted to the remote end of the line to block reclosing into the failed circuit breaker. The existing Buchanan South relay scheme does not provide this feature at present and should, therefore, be modified.

At the Buchanan South Substation, only two circuit breakers were equipped with automatic reclosing. The high-speed reclosing relays for circuit breaker No. 6, one of two protecting the W97 and W98, 345-kV lines, had been removed from service to protect the Indian Point No. 3 generator from the excessive shaft torque that could develop during reclosing operations. A slow-speed reclosing system was in service on circuit breaker No. 5, one of two circuit breakers protecting the Y88 and W98, 345-kV lines, but it correctly did not reclose, because it was locked out because of the incorrect breaker-failure operation on circuit breaker No. 6.

Neither Millwood West circuit breakers on the W98, 345-kV line reclosed as designed following the trip of the line at 8:37 p.m. This was because a loose locking nut on a control-valve linkage allowed the control-valve adjustment to change on circuit breaker No. 18. With the 675-psig setting of the operating air pressure regulator, the pressure dropped below the low-pressure lockout (550 psig) when the circuit breaker operated to clear the 8:37 p.m. fault on the W98, 345-kV line. Because there was insufficient air pressure for the circuit breaker to reclose and reopen, if the line fault was still present, automatic reclosing was correctly prevented.

Before the second system disturbance, at 8:55:53 p.m., all circuit breakers at Buchanan South Substation were open, the Indian Point No. 3 generator was out of service, the Y88, 345-kV line between Ladentown and Buchanan South was out of service, the W98, 345-kV line between Buchanan South and Millwood West was open at both ends, and the W97, 345-kV line was energized from Millwood West only. At 8:55:53 p.m., a direct lightning stroke on a double-circuit tower south of the Millwood West Substation caused a phase-C-to-ground fault on both 345-kV circuits—Buchanan North to Sprain Brook (W93/W79) and Millwood West to Sprain Brook (W99/W64), both via Eastview Substation. All reclosing performed as designed, but the Buchanan North circuit breaker could not automatically reclose, because with the Y88, 345-kV line between Ladentown and Buchanan South open, there was no direct tie to Ramapo Substation and, therefore, the phase angle across the Buchanan North circuit breaker exceeded the setting on the synchronism-check relay.[7] This greater angle prevented automatic reclosing. The 20-degree phase angle setting on the synchronism-check relay was based upon Indian Point No. 2 generator manufacturer's recommendation to prevent excessive turbine-generator shaft torque. The Buchanan North permissive automatic-reclosing angle has since been increased to 40 degrees, and the supervisory control circuit synchronism-check relays at 345-kV substations have been temporarily bypassed to permit remote

[6]An auxiliary relay is a relay whose function is assisting another relay or control device in performing a general function by supplying supplementary actions.

[7]A synchronism-check relay is a verification relay with the function of operating when two input voltages are within predetermined phasor limits.

manual reclosing in an emergency regardless of the phase angle. All protective devices performed as 'esigned during this incident.

Twenty-six cycles (0.433 second) after the second incident, circuit breakers Nos. 4 and 6 at Millwood West opened, followed by reclosure and tripping of circuit breaker No. 6 in 28 cycles (0.466 second) and 3.5 cycles (0.0583 second), respectively. These operations were associated with the W81, 345-kV line between Millwood West and Pleasant Valley. Examination of the protective equipment on the W81, 345-kV line at Millwood West revealed that a directional-distance-relay contact was bent into a continuous trip position so that a fault-detector relay in series with the distance relay operated as a result of increased W81, 345-kV line loading caused by the outages of the W93/W79 and W99/W64, 345-kV lines.

At 9:19:11 p.m., with several major interconnections out of service, the Pleasant Valley to Leeds 92, 345-kV line, which had been loaded in excess of its short-time emergency rating for about 23 minutes, tripped because of a phase-B-to-ground fault. As reported in Con Edison's First Phase Report, dated July 26, 1977, the Leeds terminal took 50 cycles (0.833 second) to open (circuit breakers R92 and R9293), and Pleasant Valley circuit breaker RNS4 opened in 55.5 cycles (0.925 second). Pleasant Valley circuit breaker RNS4 reclosed in 31.5 cycles (0.525 second) and reopened in 11.5 cycles (0.1917 second). For the high-speed reclosing to be activated, the initial tripout of 92, 345-kV line had to be by primary or first-line protective relay action. The 50- and 55.5-cycle initial clearing times for the 92, 345-kV line for first-line protective relay action are slow. Furthermore, the automatic reclosing of the Leeds circuit breaker after 21 seconds and the 23-cycle (0.383-second) clearing after reclosure are unusual. According to the circuit-breaker operating times given, the 92, 345-kV line protective relay scheme warrants further investigation.

At 9:22:47 p.m., the W81, 345-kV line was energized through energy control center supervisory control by closing Millwood West circuit breaker No. 6. Three and one-half cycles (0.0583 second) later the Pleasant Valley circuit breaker No. RNS2 opened that line terminal. If the line opened, as reported, because of the large power surge resulting from the existing transmission system configuration, it is unclear why the line tripped only at the Pleasant Valley end. This also warrants further investigation.

All other protective relay operations after this time and before the islanding of the Con Edison system appear to have functioned as designed to protect associated electric power system apparatus. Con Edison has reported that 599 protective relay operations occurred during the July 13, 1977, disturbance with the malfunction of only two relays.

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Appendix H

CON EDISON'S RELAY TESTING AND MAINTENANCE PROGRAM

The Technical Services and Development Department of Con Edison has the responsibility for testing, calibrating, setting, and maintaining all system protective relaying equipment. This department, which includes 52 management and 230 union personnel, develops and prepares testing and maintenance procedures. Since 1972, new test technicians have been recruited from local two-year colleges and have been trained by Con Edison. New employees spend, depending on individual capabilities, about 2 years in the central laboratory under close supervision before they are permitted to assist in field testing and maintenance of equipment. Initial field assignments, assisting journeyman testers, continue the on-the-job training. Following satisfactory performance as an assistant, individuals are elevated to journeyman status. As such they will individually perform system equipment testing and maintenance functions.

In 1970, the scheduling of relay testing and maintenance was incorporated in a computerized system to assure more effectively the timely performance of testing and maintenance on all relay equipment. Evidence of the effectiveness of this program is shown in the plots of relay test status, figure H-1, and relay trip test status, figure H-2, for the 1972 to mid-1977 period. Figures H-3 and H-4 display the relay test and trip test computer-generated summaries as of July and August 1977 for over 4,200 relay items. The present practice is to perform routine calibration and tripping tests every year for protective devices associated with system equipment operating at voltages at 69 kV and higher. They are considered overdue after 2 years. The test interval for equipment operating at lower voltages is every 2 years; they become overdue after 3 years except in a few cases. The computer master list for several substations as of July 1977 is shown in figure H-5. Figures H-6 and H-7 show the computer monthly statuses of relay tests and trip tests and the priority (PRI) statuses of the components.

Testing involves applying electrical currents and voltages with the proper phase relationship to verify or calibrate the expected relay characteristics. In addition, a trip test is performed to verify that the relay functions properly as a protective relay-scheme component.

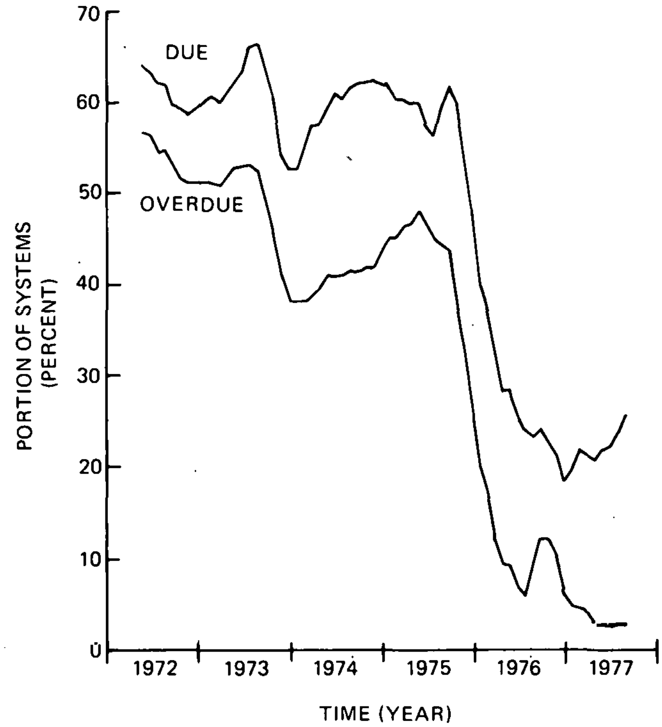

Figure H-2.–Trip test status, Con Edison relay equipment, 1972 to mid-1977 (from Con Edison Technical Services and Development Department).

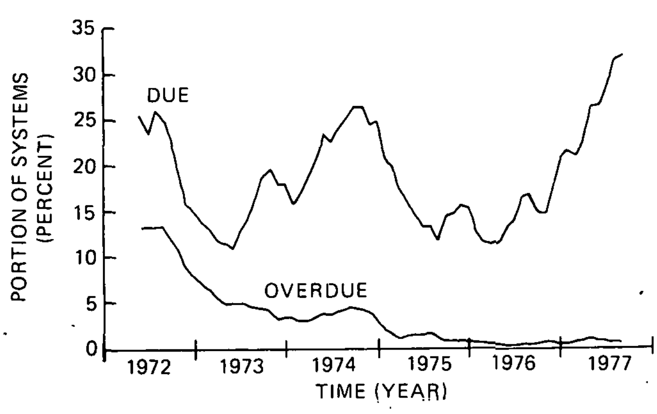

Figure H-1.–Relay test status, Con Edison relay equipment, 1972 to mid-1977 (from Con Edison Technical Services and Development Department).

RELAY TEST SUMMARY 7/77 PAGE 1

LOCATION	VOLTAGE	TOTAL ITEMS	DUE NO.	DUE OVER 6 MONTHS NO.	OVERDUE NO.	OVERDUE PCNT.**	SYS TESTED SINCE 1/77 NO.	SYS TESTED SINCE 1/77 PCNT.**
MANHATTAN AND BRONX SS	4-20KV	1095	305	40	0	0.0	161	14.7
	23-45KV	26	17	4	0	0.0	3	11.5
	69-138KV	261	107	31	0	0.0	81	31.0
	230-345KV	26	18	9	5	19.2	3	11.5
	MISC.	99	32	3	0	0.0	19	19.2
	TOTAL	1507	479	87	5	0.3	267	17.7
BROOKLYN AND QUEENS SS	4-20KV	696	170	79	1	0.1	140	20.1
	23-45KV	509	137	52	1	0.2	103	20.2
	69-138KV	162	115	58	9	5.6	23	14.2
	230-345KV	91	37	14	4	4.4	29	31.9
	MISC.	81	32	10	0	0.0	19	23.5
	TOTAL	1539	491	213	15	1.0	314	20.4
STATEN ISLAND SS	4-20KV	243	93	22	3	1.2	0	0.0
	23-45KV	110	33	11	0	0.0	0	0.0
	69-138KV	41	33	19	9	22.0	1	2.4
	230-345KV	17	7	5	0	0.0	0	0.0
	MISC.	5	5	2	2	40.0	0	0.0
	TOTAL	416	171	59	14	3.4	1	0.2
NORTHERN WESTCHESTER SS	4-20KV	785	103	12	0	0.0	156	19.9
	23-45KV	7	2	2	1	14.3	3	42.9
	69-138KV	115	44	6	0	0.0	40	34.8
	230-345KV	150	47	1	1	0.7	36	24.0
	MISC.	40	10	1	0	0.0	15	37.5
	TOTAL	1097	206	22	2	0.2	250	22.8
LOWER WESTCHESTER SS	4-20KV	171	5	0	0	0.0	17	9.9
	23-45KV	12	0	0	0	0.0	2	16.7
	69-138KV	4	0	0	0	0.0	3	75.0
	230-345KV	0	0	0	0	0.0	0	0.0
	MISC.	1	0	0	0	0.0	1	100.0
	TOTAL	188	5	0	0	0.0	23	12.2
WHOLE SYSTEM	4-20KV	2990	676	153	4	0.1	474	15.9
	23-45KV	664	189	69	2	0.3	111	16.7
	69-138KV	583	299	114	18	3.1	148	25.4
	230-345KV	284	109	29	10	3.5	68	23.9
	MISC.	226	79	16	2	0.9	54	23.9
	TOTAL	4747	1352	381	36	0.8	855	18.0

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MANHATTAN AND BRONX SS	4-20KV	1095	355	69	0	0.0	170	15.5
	23-45KV	26	13	1	0	0.0	7	26.9
	69-138KV	261	124	38	0	0.0	93	35.6
	230-345KV	26	16	9	5	19.2	5	19.2
	MISC.	99	27	7	0	0.0	25	25.3
	TOTAL	1507	535	124	5	0.3	300	19.9
BROOKLYN AND QUEENS SS	4-20KV	696	198	76	1	0.1	145	20.8
	23-45KV	511	138	50	1	0.2	116	22.7
	69-138KV	161	107	62	5	3.1	30	18.6
	230-345KV	91	51	14	0	0.0	33	36.3
	MISC.	81	30	12	0	0.0	21	25.9
	TOTAL	1540	524	214	7	0.5	345	22.4
STATEN ISLAND SS	4-20KV	247	139	41	5	2.0	4	1.6
	23-45KV	110	52	15	0	0.0	0	0.0
	69-138KV	45	32	22	8	17.8	7	15.6

** - PERCENT OF TOTAL ITEMS

Figure H-3.–Relay test summary, Con Edison relay equipment, as of July and August 1977 (from Con Edison Technical Services and Development Department).

LOCATION	VOLTAGE	TOTAL ITEMS	DUE NO.	DUE OVER 6 MONTHS NO.	OVERDUE NO.	OVERDUE PCNT.**	SYS TESTED SINCE 1/77 NO.	SYS TESTED SINCE 1/77 PCNT.**
	230-345KV	17	6	6	0	0.0	5	29.4
	MISC.	5	5	2	2	40.0	0	0.0
	TOTAL	424	234	86	15	3.5	16	3.8
NORTHERN WESTCHESTER SS	4-20KV	788	87	10	0	0.0	195	24.7
	23-45KV	1	0	0	0	0.0	0	0.0
	69-138KV	115	45	7	0	0.0	42	36.5
	230-345KV	150	58	5	1	0.7	38	25.3
	MISC.	40	11	1	0	0.0	15	37.5
	TOTAL	1094	201	23	1	0.1	290	26.5
LOWER WESTCHESTER SS	4-20KV	171	5	1	0	0.0	17	9.9
	23-45KV	10	0	0	0	0.0	2	20.0
	69-138KV	4	0	0	0	0.0	3	75.0
	230-345KV	0	0	0	0	0.0	0	0.0
	MISC.	1	0	0	0	0.0	1	100.0
	TOTAL	186	5	1	0	0.0	23	12.4
WHOLE SYSTEM	4-20KV	2997	784	197	6	0.2	531	17.7
	23-45KV	658	203	66	1	0.2	125	19.0
	69-138KV	586	308	129	13	2.2	175	29.9
	230-345KV	284	131	34	6	2.1	81	28.5
	MISC.	226	73	22	2	0.9	62	27.4
	TOTAL	4751	1499	448	28	0.6	974	20.5

** - PERCENT OF TOTAL ITEMS

Figure H-3 (concluded).–Relay test summary, Con Edison relay equipment, as of July and August 1977 (from Con Edison Technical Services and Development Department).

TRIP TEST SUMMARY
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LOCATION	VOLTAGE	TOTAL ITEMS	DUE NO.	DUE OVER 6 MONTHS NO.	OVERDUE NO.	OVERDUE PCNT.**	SYS TESTED SINCE 1/77 NO.	SYS TESTED SINCE 1/77 PCNT.**
MANHATTAN AND BRONX SS	4-20KV	919	202	2	2	0.2	42	4.6
	23-45KV	24	13	0	0	0.0	5	20.8
	69-138KV	245	107	24	6	2.4	104	42.4
	230-345KV	26	15	9	2	7.7	5	19.2
	MISC.	7	0	0	0	0.0	3	42.9
	TOTAL	1221	337	35	10	0.8	159	13.0
BROOKLYN AND QUEENS SS	4-20KV	681	83	40	9	1.3	65	9.5
	23-45KV	450	84	12	8	1.8	156	34.7
	69-138KV	160	110	67	21	13.1	38	23.8
	230-345KV	85	58	20	6	7.1	18	21.2
	MISC.	11	7	5	5	45.5	0	0.0
	TOTAL	1387	342	144	49	3.5	277	20.0
STATEN ISLAND SS	4-20KV	236	25	15	12	5.1	0	0.0
	23-45KV	110	17	11	5	4.5	1	0.9
	69-138KV	37	35	32	11	29.7	2	5.4
	230-345KV	16	8	6	0	0.0	3	18.8
	MISC.	0	0	0	0	0.0	0	0.0
	TOTAL	399	85	64	28	7.0	6	1.5
NORTHERN WESTCHESTER SS	4-20KV	759	53	4	0	0.0	110	14.5
	23-45KV	7	3	2	1	14.3	3	42.9
	69-138KV	108	33	9	5	4.6	64	59.3
	230-345KV	139	67	34	17	12.2	44	31.7
	MISC.	3	2	0	0	0.0	0	0.0
	TOTAL	1016	158	49	23	2.3	221	21.8

** - PERCENT OF TOTAL ITEMS

Figure H-4.–Trip test summary, Con Edison relay equipment, as of July and August 1977 (from Con Edison Technical Services and Development Department).

LOCATION	VOLTAGE	TOTAL ITEMS	DUE NO.	DUE OVER 6 MONTHS NO.	OVERDUE NO.	OVERDUE PCNT.**	SYS TESTED SINCE 1/77 NO.	SYS TESTED SINCE 1/77 PCNT.**
LOWER WESTCHESTER SS	4-20KV	168	13	1	0	0.0	15	8.9
	23-45KV	12	0	0	0	0.0	2	16.7
	69-138KV	4	4	4	0	0.0	0	0.0
	230-345KV	0	0	0	0	0.0	0	0.0
	MISC.	1	0	0	0	0.0	1	100.0
	TOTAL	185	17	5	0	0.0	18	9.7
WHOLE SYSTEM	4-20KV	2763	376	62	23	0.8	232	8.4
	23-45KV	603	117	25	14	2.3	167	27.7
	69-138KV	554	289	136	43	7.8	208	37.5
	230-345KV	266	148	69	25	9.4	70	26.3
	MISC.	22	9	5	5	22.7	4	18.2
	TOTAL	4208	939	297	110	2.6	681	16.2

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MANHATTAN AND BRONX SS	4-20KV	919	253	2	2	0.2	42	4.6
	23-45KV	24	13	0	0	0.0	5	20.8
	69-138KV	245	130	31	6	2.4	110	44.9
	230-345KV	26	15	11	2	7.7	5	19.2
	MISC.	7	0	0	0	0.0	3	42.9
	TOTAL	1221	411	44	10	0.8	165	13.5
BROOKLYN AND QUEENS SS	4-20KV	681	100	41	16	2.3	65	9.5
	23-45KV	452	79	43	8	1.8	174	38.5
	69-138KV	159	106	80	19	11.9	43	27.0
	230-345KV	85	61	25	8	9.4	18	21.2
	MISC.	11	7	5	5	45.5	0	0.0
	TOTAL	1388	353	194	56	4.0	300	21.6
STATEN ISLAND SS	4-20KV	240	26	15	12	5.0	8	3.3
	23-45KV	110	20	11	5	4.5	1	0.9
	69-138KV	39	31	30	8	20.5	8	20.5
	230-345KV	16	2	2	0	0.0	12	75.0
	MISC.	0	0	0	0	0.0	0	0.0
	TOTAL	405	79	58	25	6.2	29	7.2
NORTHERN WESTCHESTER SS	4-20KV	762	44	5	0	0.0	126	16.5
	23-45KV	1	0	0	0	0.0	0	0.0
	69-138KV	108	31	13	5	4.6	66	61.1
	230-345KV	139	59	36	19	13.7	52	37.4
	MISC.	3	2	0	0	0.0	0	0.0
	TOTAL	1013	136	54	24	2.4	244	24.1
LOWER WESTCHESTER SS	4-20KV	168	13	1	1	0.6	15	8.9
	23-45KV	10	0	0	0	0.0	2	20.0
	69-138KV	4	3	3	0	0.0	1	25.0
	230-345KV	0	0	0	0	0.0	0	0.0
	MISC.	1	0	0	0	0.0	1	100.0
	TOTAL	183	16	4	1	0.5	19	10.4
WHOLE SYSTEM	4-20KV	2770	436	64	31	1.1	256	9.2
	23-45KV	597	112	54	13	2.2	182	30.5
	69-138KV	555	301	157	38	6.8	228	41.1
	230-345KV	266	137	74	29	10.9	87	32.7
	MISC.	22	9	5	5	22.7	4	18.2
	TOTAL	4210	995	354	116	2.8	757	18.0

** - PERCENT OF TOTAL ITEMS

Figure H-4 (concluded).–Trip test summary, Con Edison relay equipment, as of July and August 1977 (from Con Edison Technical Services and Development Department).

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LOCATION	CODE	SEQUENCE	VOLTAGE	EQUIPMENT PROTECTED	INSP.	CALIB.	LAST	TRIP	CHANGE SETTING STATUS REPORT	IC
OSSINING	675									
		1	13	*FDR 6W64-9740 POS 1	6/79	6/81	6/77	6/77		24
		2	13	*FDR 7W43 POS 2	3/79	3/81	3/77	3/77		24
		3	13	*FDR 9724 POS 3	1/78	1/80	1/76	1/76		24
		4	13	*FDR 6W62 POS 4	4/79	4/81	4/77	4/77		24
		7	13	*FDR 7W44 POS 8	3/79	3/81	3/77	3/77		24
		8	13	*FDR 7W42 POS 11	2/80	2/78	1/74	2/76		24
		9	13	*FDR 6W61 POS 12	3/79	3/81	3/77	3/77		24
		10	13	FDR 6W63 POS 13	3/79	3/81	3/77	3/77		24
		11	13	FDR 7W47 POS 16	2/80	2/78	12/74	2/76		24
		12	13	*BANK 1	1/80	1/78	2/74	1/76		24
		13	13	*BANK 2	1/80	1/78	1/74	1/76		24
		16	13	BUS SEC 1	1/80	1/78	2/74	1/76		24
		17	13	BUS SEC 2	2/80	2/78	2/74	2/76		24
		20	4	FEEDER 641	11/79	11/77	10/73	11/75		24
		21	4	FEEDER 642	12/78	12/80	12/76	12/76		24
		22	4	FEEDER 643	12/78	12/80	12/76	5/77		24
		23	4	FEEDER 644	12/78	12/80	12/76	12/76		24
		24	4	FEEDER 645	12/78	12/80	12/76	5/77		24
		25	4	FEEDER TRANSF	12/78	12/80	12/76	12/76		24
		26	4	FEEDER L&P	12/79	12/77	11/73	12/75		24
		27	4	FEEDER 646	12/78	12/80	12/76	6/77		24
		40	125	DC LOAD BOARD	4/79	4/81	4/77	99		24
MILLWOOD EAST	680									
		1	138	FDR 9825 BKR 5E	11/77	11/80	11/76	3/77		14
		2	138	FDR 9826 BKR 6E	12/77	12/80	12/76	2/77		14
		8	138	*BUS 1	12/77	12/80	12/76	5/76		14
		9	138	*BUS 2	12/77	12/80	12/76	5/76		14
		50	0	OSCILOGR HATH OS12	7/78	7/78	7/77	99		11
		60	125	DC LOAD BOARD	5/77	5/79	5/75	99		24
MILLWOOD WEST	681									
		3	345	F W83 PRI BUS 2-4	6/77	6/80	6/76	12/75		14
		4	345	F W83 SEC BUS 2-4	6/77	6/80	6/76	12/75		14
		7	345	F W81 PRI BUS 4-6	8/77	8/80	8/76	6/77		14
		8	345	F W81 SEC BUS 4-6	8/77	8/80	8/76	6/77		14
		11	345	F W84 PRI BUS 7-9	3/78	3/81	3/77	12/76		14
		12	345	F W84 SEC BUS 7-9	3/78	3/81	3/77	12/76		14
		13	345	F W82 PRI BUS 8-10	5/77	5/80	5/76	12/75		14
		14	345	F W82 SEC BUS 8-10	4/77	4/80	4/76	12/75		14
		15	345	F W80 PRI BUS 9-11	8/77	8/80	8/76	5/77		14
		16	345	F W80 SEC BUS 9-11	8/77	8/80	8/76	5/77		14
		17	345	F W97 PRI BUS 10-12	7/77	7/80	7/76	10/75		14
		18	345	F W97 SEC BUS 10-12	7/77	7/80	7/76	10/75		14
		21	345	F W99 PRI BUS 14-16	9/77	9/80	9/76	11/76		14
		22	345	F W99 SEC BUS 14-16	9/77	9/80	9/76	11/76		14
		25	345	F W98 PRI BUS 16-18	5/78	5/81	5/77	10/75		14
		26	345	F W98 SEC BUS 16-18	5/78	5/81	5/77	10/75		14
		31	345	EAST SYN BUS BK TA	6/77	6/80	6/76	11/76		14

Figure H-5.—Selected pages of computer master list for Con Edison substations, as of July 1977 (from Con Edison Technical Services and Development Department).

LOCATION	CODE	SEQUENCE	VOLTAGE	EQUIPMENT PROTECTED	INSP.	CALIB.	LAST	TRIP	CHANGE SETTING STATUS REPORT	IC
MILLWOOD WEST	(CONTINUED)									
		33	345	WEST SYN BUS	11/77	11/80	11/76	4/77		14
		44	345	BREAKER 2	9/77	9/80	9/76	3/77		14
		46	345	BREAKER 4	9/77	9/80	9/76	3/77		14
		48	345	BREAKER 6	9/77	9/80	9/76	4/77		14
		49	345	BREAKER 7	9/77	9/80	9/76	3/77		14
		50	345	BREAKER 8	9/77	9/80	9/76	4/77		14
		51	345	BREAKER 9	9/77	9/80	9/76	3/77		14
		52	345	BREAKER 10	9/77	9/80	9/76	4/77		14
		53	345	BREAKER 11	10/77	10/80	10/76	4/77		14
		54	345	BREAKER 12	9/77	9/80	9/76	4/77		14
		56	345	BREAKER 14	9/77	9/80	9/76	4/77		14
		58	345	BREAKER 16	9/77	9/80	9/76	4/77		14
		60	345	BREAKER 18	10/77	10/80	10/76	4/77		14
		66	138	F 96961-96951 BUS 1W	7/77	7/80	7/76	9/75		14
		68	138	F 96962 BUS 2W	1/78	1/81	1/77	1/77		14
		69	138	F 96952 BKR5W BUS 2W	6/78	6/81	6/77	6/77		14
		70	138	F 96921 BUS 2W	1/78	1/81	1/77	1/77		14
		95	345	ATTT-SS W82 RT1	1/78	1/79	1/77	3/76		11
		96	345	ATTT-SS W82 RT2	1/78	1/79	1/77	3/76		11
		97	345	ATTT-SS W83 RT1	7/77	7/78	7/76	5/75		11
		98	345	ATTT-SS W83 RT2	7/77	7/78	7/76	5/75		11
		99	345	ATTT-SS W84 RT1	6/79	6/78	4/76	6/77		11
		100	345	ATTT-SS W84 RT2	6/79	6/78	4/76	6/77		11
		125	345	ATTT-SS W99 RT1	1/78	1/79	1/77	1/77		11
		126	345	ATTT-SS W99 RT2	1/78	1/79	1/77	1/77		11
		133	138	ATTT-SS 96951 RT1	1/78	1/79	1/77	1/77		11
		134	138	ATTT-SS 96951 RT2	1/78	1/79	1/77	1/77		11
		135	138	ATTT-SS 96952 RT1	1/78	1/79	1/77	1/77		11
		136	138	ATTT-SS 96952 RT2	1/78	1/79	1/77	1/77		11
		141	125	DC CONTROL BOARD 1	3/79	3/81	3/77	99		24
		142	125	DC CONTROL BOARD 2	3/79	3/81	3/77	99		24
		143	125	DC CONTROL BD 138 YD	3/79	3/81	3/77	99		24
		151	0	OSCILLOGR HATH RS32	4/78	4/78	4/77	99		11
MILLWOOD WEST 13KV	683									
		1	138	BANK 1	6/77	6/80	6/76	11/76		14
		2	138	SUDDEN PRESSURE BK 1	3/78	3/81	3/77	99		14
		3	138	BANK 2	6/77	6/80	6/76	11/76		14
		6	13	BUS SEC 1N	7/79	7/81	7/77	1/77		24
		7	13	BUS SEC 1S	7/79	7/81	7/77	1/77		24
		15	13	FDR 7W41 SW POS 11N	2/79	2/81	2/77	1/77		24
		16	13	FDR 7W47 SW POS 11S	5/79	5/81	5/77	9/75		24
		17	13	FDR 7W42 SW POS 12N	6/79	6/81	6/77	1/77		24
		18	13	FDR 7W45 SW POS 12S	6/79	6/81	6/77	1/77		24
		25	13	FDR 7W40 SW POS 21N	6/79	6/81	6/77	1/77		24
		26	13	FDR 7W44 SW POS 21S	6/79	6/81	6/77	1/77		24
		27	13	FDR 7W43 SW POS 22N	6/79	6/81	6/77	1/77		24
		28	13	FDR 7W46 SW POS 22S	6/79	6/81	6/77	1/77		24
		51	125	DC LOAD BOARD	3/79	3/81	3/77	99		24

LOCATION	CODE	SEQUENCE	VOLTAGE	EQUIPMENT PROTECTED	INSP.	CALIB.	LAST	TRIP	CHANGE SETTING STATUS REPORT	IC
BUCHANAN 13KV	(CONTINUED)									
		40	13	*FDR 13W93 POS F3-1	1/79	1/81	1/77	1/77		24
		41	13	FDR 13W83 POS F3-2	7/78	7/80	7/76	1/77		24
		42	13	FDR 13W80 POS F3-3	7/78	7/80	7/76	1/77		24
		43	13	FDR 13W86 POS F3-4	10/79	10/77	10/73	1/77		24
		44	13	FDR 13W88 POS F3-5	1/79	1/81	1/77	3/77		24
		45	13	FDR 13W89 POS F3-6	7/78	7/80	7/76	3/77		24
		46	13	FDR 13W90 POS F3-7	7/78	7/80	7/76	3/77		24
		50	13	L&P 2 POS LP2	7/78	7/80	7/76	5/75		24
BUCHANAN	695									
		2	138	*FEEDER 95331	11/77	11/80	11/76	4/77		14
		3	138	FEEDER 96951	12/77	12/80	12/76	4/77		14
		4	138	FEEDER 96952	12/77	12/80	12/76	4/77		14
		5	138	FDR 95332 BUS SECT 4	5/77	5/78	11/73	4/76		14
		10	138	BANK 1	7/77	7/80	7/76	6/75		14
		11	138	BANK 2	1/78	1/81	1/77	4/77		14
		12	138	BANK 3	2/78	2/81	2/77	3/76		14
		14	138	BUS SEC 1	7/77	7/80	7/76	6/75		14
		15	138	BUS SEC 2	4/77	4/78	1/74	4/77		14
		16	138	BUS SEC 3	4/77	4/78	12/73	4/76		14
		32	125	DC LOAD BOARD 1	6/79	6/81	6/77	99		24
		33	125	DC LOAD BOARD 2	6/79	6/81	6/77	99		24
		36	0	OSCILOGR GE PM21	3/77	3/77	3/76	99		11
		37	125	DC LOAD BOARD 5	6/79	6/81	6/77	99		24
		38	125	DC LOAD BOARD 6	6/79	6/81	6/77	99		24
		41	4	LOAD SHED ROC RELAY	6/78	6/78	6/77	5/76		11
		51	138	ATTT-SS 96951 RT1	1/78	1/79	1/77	1/77		11
		52	138	ATTT-SS 96951 RT2	1/78	1/79	1/77	1/77		11
		53	138	ATTT-SS 96952 RT1	1/78	1/79	1/77	6/77		11
		54	138	ATTT-SS 96952 RT2	1/78	1/79	1/77	6/77		11
BUCHANAN 345KV	696									
		1	345	F W96 PRI BUS 1-3	9/77	9/80	9/76	9/76		14
		2	345	F W96 SEC BUS 1-3	9/77	9/80	9/76	9/76		14
		5	345	F W98 PRI BUS 3-5	8/77	8/80	8/76	4/75		14
		6	345	F W98 SEC BUS 3-5	8/77	8/80	8/76	4/75		14
		7	345	FDR 97&98 OVER LOAD	3/78	3/81	3/77	2/77		14
		9	345	F W97 PRI BUS 4-6	8/77	8/80	8/76	4/75		14
		10	345	F W97 SEC BUS 4-6	8/77	8/80	8/76	4/75		14
		11	345	F Y88 PRI BUS 5-6	10/77	10/80	10/76	4/77		14
		12	345	F Y88 SEC BUS 5-6	10/77	10/80	10/76	4/77		14
		13	345	ATTT-SS Y88	6/77	6/78	6/76	4/74		11
		17	345	F W95 PRI BUS 7-9	4/78	4/81	4/77	7/77		14
		18	345	F W95 SEC BUS 7-9	4/78	4/81	4/77	7/77		14
		19	345	F Y94 PRI BUS 7-11	12/77	12/80	12/76	11/76		14
		20	345	F Y94 SEC BUS 7-11	12/77	12/80	12/76	11/76		14
		23	345	F W93 PRI BUS 9-11	8/77	8/80	8/76	11/76		14
		24	345	F W93 SEC BUS 9-11	8/77	8/80	8/76	11/76		14
		25	345	ATTT-SS W93 RT1	9/77	9/78	9/76	9/76		11

Figure H-5 (continued).—Selected pages of computer master list for Con Edison substations, as of July 1977 (from Con Edison Technical Services and Development Department).

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LOCATION	CODE	SEQUENCE	VOLTAGE	EQUIPMENT PROTECTED	INSP.	CALIB.	LAST	TRIP	CHANGE	SETTING	STATUS REPORT	IC
BUCHANAN 345KV	(CONTINUED)											
		26	345	ATTT-SS W93 RT2	9/77	9/78	9/76	9/76				11
		27	345	BANK TA-5 FDR 95891	2/78	2/81	2/77	8/77				14
		28	345	SUDDEN PRESSURE TA-5	9/77	9/80	9/76	99				14
		31	345	BREAKER 1	9/77	9/80	9/76	5/75	8/77			14
		33	345	BREAKER 3	9/77	9/80	9/76	5/75	8/77			14
		35	345	BREAKER 5	10/77	10/80	10/76	5/75	8/77			14
		36	345	BREAKER 6	10/77	10/80	10/76	5/75	8/77			14
		37	345	BREAKER 7	5/78	5/81	5/77	11/76	8/77			14
		39	345	BREAKER 9	5/78	5/81	5/77	11/76	8/77			14
		41	345	BREAKER 11	5/78	5/81	5/77	11/76	8/77			14
		50	0	OSCILOGR.HATH.MD-32	4/78	4/78	4/77	99				11
PLEASANT VALLEY	702											
		2	345	BANK SI- SOUTH BUS	5/77	5/80	5/76	3/76				14
		3	345	FEEDER 398	11/77	11/80	11/76	9/76				14
		4	345	FEEDER 81	11/77	11/80	11/76	6/77				14
		5	345	FEEDER 80	11/77	11/80	11/76	5/77				14
		6	345	FEEDER 91	11/77	11/80	11/76	6/77				14
		7	345	FEEDER 92	11/77	11/80	11/76	6/77				14
		10	345	BREAKER RN2	11/77	11/80	11/76	9/76				14
		11	345	BREAKER RNS2	11/77	11/80	11/76	9/76				14
		12	345	BREAKER RS3	11/77	11/80	11/76	11/76				14
		13	345	BREAKER RNS4	11/77	11/80	11/76	~~8/64~~ 6/77 Dep				14
BOXWOOD 106	794											
		1	13	BANK FDR 4W02	9/78	9/80	9/76	3/76				24
		3	4	BUS	9/78	9/80	9/76	3/76				24
		5	4	FDR 106U3 CUB 4	9/78	9/80	9/76	3/76				24
		6	4	SPARE CUB 5	9/78	9/80	9/76	99				24
		7	4	FDR 106U2 CUB 6	9/78	9/80	9/76	3/76				24
		8	4	FDR 106U1 CUB 7	9/78	9/80	9/76	3/76				24
SHAWNEE 103	797											
		1	13	BANK FDR 5W42	2/80	2/78	11/73	12/75				24
		3	4	BUS	2/80	2/78	11/73	12/75				24
		5	4	FDR 103U1 CUB 4	12/79	12/77	5/73	12/75				24
		6	4	FDR 103U2 CUB 5	12/79	12/77	11/73	12/75				24
		7	4	SPARE CUB 6	2/80	2/78	11/73	99				24
		8	4	SPARE CUB 7	2/80	2/78	5/75	99				24
ARDSLEY 1	801											
		1	13	BANK FDR 12W03	7/78	7/80	7/76	1/76				24
		3	4	BUS	7/78	7/80	7/76	1/76				24
		5	4	FDR 1U1 CUB 4	8/78	8/80	8/76	1/76				24
		6	4	FDR 1U2 CUB 5	8/78	8/80	8/76	1/76				24
		7	4	FDR 1U4 CUB 6	8/78	8/80	8/76	1/76				24
		8	4	FDR 1U3 CUB 7	8/78	8/80	8/76	1/76				24

Figure H-5 (concluded).—Selected pages of computer master list for Con Edison substations, as of July 1977 (from Con Edison Technical Services and Development Department).

LOCATION	CODE	VOLT.	EQUIPMENT PROTECTED	9/77	10/77	11/77	PRI
HARRISON	(CONTINUED)						
		113	UNDERFREQ BANK NO2			I	6
		113	UNDERFREQ BANK NO3			I	6
ELMSFORD	660						
		138	*BANK 1	I			6
		138	*BANK 2	I			4 - 4
		138	BUS SEC2W	I			5 - 2
ELMSFORD NO 1	661						
		13	BUS SEC 4	C			5 - 1
ELMSFORD NO 2	662		NO TESTS REQUIRED AT THIS LOCATION				
EASTVIEW	664						
		138	BREAKER 1		I		6
		138	BREAKER 2		I		6
		138	BREAKER 3		I		6
		138	BREAKER 4		I		6
		138	BREAKER 5		I		6
		138	BREAKER 6		I		6
		138	BREAKER 7		I		6
		138	BREAKER 8		I		6
		345	ATTT-SS W79-W93 RT1	I			6
		345	ATTT-SS W79-W93 RT2	I			6
TARRYTOWN	665		NO TESTS REQUIRED AT THIS LOCATION				
PLEASANTVILLE	668						
		13	F14W05 SW11			I	6
		345	BANK 1 FDR W83-89	I			5 - 4
		345	ATTT-SS W83-W89 RT1	I			5 - 2
		345	ATTT-SS W83-W89 RT2	I			5 - 2
		345	BANK 2 FDR W84-90	I			5 - 4
OSSINING	675						
		4	FEEDER 641			C	6
MILLWOOD EAST	680						
		138	FDR 9825 BKR 5E			I	6
		125	DC LOAD BOARD	I			5 - 4
MILLWOOD WEST	681						
		345	F W83 PRI BUS 2-4	I			5 - 3
		345	F W83 SEC BUS 2-4	I			5 - 3
		345	F W81 PRI BUS 4-6	I			5 - 1
		345	F W81 SEC BUS 4-6	I			5 - 1
		345	F W82 PRI BUS 8-10	I			5 - 4
		345	F W82 SEC BUS 8-10	I			5 - 5
		345	F W80 PRI BUS 9-11	I			5 - 1
		345	F W80 SEC BUS 9-11	I			5 - 1
		345	F W97 PRI BUS 10-12	I			5 - 2
		345	F W97 SEC BUS 10-12	I			5 - 2
		345	F W99 PRI BUS 14-16	I			6
		345	F W99 SEC BUS 14-16	I			6
		345	EAST SYN BUS BK TA	I			5 - 3
		345	WEST SYN BUS			I	6
		345	BREAKER 2	I			6
		345	BREAKER 4	I			6
		345	BREAKER 6	I			6
		345	BREAKER 7	I			6
		345	BREAKER 8	I			6
		345	BREAKER 9	I			6
		345	BREAKER 10	I			6
		345	BREAKER 11		I		6
		345	BREAKER 12	I			6
		345	BREAKER 14	I			6
		345	BREAKER 16	I			6

Figure H-6.–Monthly statuses of Con Edison relay tests and priority (PRI) statuses of components (from Con Edison Technical Services and Development Department).

LOCATION	CODE	VOLT.	EQUIPMENT PROTECTED	9/77	10/77	11/77	PRI
MILLWOOD WEST	(CONTINUED)						
		345	BREAKER 18		I		6
		138	F 96961-96951 BUS 1W	I			5 - 2
		345	ATTT-SS W83 RT1	I			5 - 2
		345	ATTT-SS W83 RT2	I			5 - 2
MILLWOOD_WEST 13KV	683						
		138	BANK 1	I			5 - 3
		138	BANK 2	I			5 - 3
MT KISCO	685						
		4	STATION L&P CUB 9	I			5 - 3
PEEKSKILL	690						
		13	*FDR 13W87 CUB 3	I			4 - 5
		13	*FDR 13W81 CUB 8	C			5 - 2
		4	TRANSFER BUS CUB 12	C			5 - 2
		4	FDR 1346 CUB 19	I			5 - 2
		125	DC LOAD BOARD	I			5 - 4
BUCHANAN 13KV	694						
		13	BUS SEC 2B			I	6
		13	FDR 13W84 POS F2-5	I			5 - 1
		13	FDR 13W87 POS F2-7	I			5 - 1
		13	FDR 13W86 POS F3-4		C		6
BUCHANAN	695						
		138	*FEEDER 95331			I	6
		138	FDR 95332 BUS SECT 4	I			5 - 4
		138	BANK 1	I			5 - 2
		138	BUS SEC 1	I			5 - 2
		138	BUS SEC 2	I			5 - 5
		138	BUS SEC 3	I			5 - 5
		0	OSCILOGR GE PM21	C			4 - 1
BUCHANAN 345KV	696						
		345	F W96 PRI BUS 1-3	I			6
		345	F W96 SEC BUS 1-3	I			6
		345	F W98 PRI BUS 3-5	I			5 - 1
		345	F W98 SEC BUS 3-5	I			5 - 1
		345	F W97 PRI BUS 4-6	I			5 - 1
		345	F W97 SEC BUS 4-6	I			5 - 1
		345	F Y88 PRI BUS 5-6		I		6
		345	F Y88 SEC BUS 5-6		I		6
		345	ATTT-SS Y88	I			5 - 3
		345	F W93 PRI BUS 9-11	I			5 - 1
		345	F W93 SEC BUS 9-11	I			5 - 1
		345	ATTT-SS W93 RT1	I			6
		345	ATTT-SS W93 RT2	I			6
		345	SUDDEN PRESSURE TA-5	I			6
		345	BREAKER 1	I			6
		345	BREAKER 3	I			6
		345	BREAKER 5		I		6
		345	BREAKER 6		I		6
PLEASANT VALLEY	702						
		345	BANK SI- SOUTH BUS	I			5 - 4
		345	FEEDER 398			I	6
		345	FEEDER 81			I	6
		345	FEEDER 80			I	6
		345	FEEDER 91			I	6
		345	FEEDER 92			I	6
		345	BREAKER RN2			I	6
		345	BREAKER RNS2			I	6
		345	BREAKER RS3			I	6
		345	BREAKER RNS4			I	6
BOXWOOD 106	794		NO TESTS REQUIRED AT THIS LOCATION				

Figure H-6 (continued).–Monthly statuses of Con Edison relay tests and priority (PRI) statuses of components (from Con Edison Technical Services and Development Department).

LOCATION	CODE	VOLT.	EQUIPMENT PROTECTED	9/77	10/77	11/77	PRI
SHAWNEE 103	797						
			NO TESTS REQUIRED AT THIS LOCATION				
ARDSLEY 1	801						
			NO TESTS REQUIRED AT THIS LOCATION				
NEPPERHAN 2	802						
		13	BANK FDR 15W04	C			5 - 4
		4	BUS	C			5 - 4

Figure H-6 (concluded).–Monthly statuses of Con Edison relay tests and priority (PRI) statuses of components (from Con Edison Technical Services and Development Department).

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LOCATION	CODE	VOLT.	EQUIPMENT PROTECTED	9/77	10/77	11/77	PRI
EASTVIEW	(CONTINUED)						
		138	BREAKER 8	1			- 3/75
		138	BUS SEC 3-5	5			- 5
		345	ATTT-SS W64-W99 RT1	4			- 1
		345	ATTT-SS W64-W99 RT2	4			- 1
		345	ATTT-SS W65-W82 RT1	4			- 1
		345	ATTT-SS W65-W82 RT2	4			- 1
		345	ATTT-SS W79-W93 RT1	4			- 1
		345	ATTT-SS W79-W93 RT2	4			- 1
TARRYTOWN	665						
			NO TESTS REQUIRED AT THIS LOCATION				
PLEASANTVILLE	668						
		13	BUS SEC 6	5			- 3
		13	SYN BUS 4SY	5			- 3
		13	F11W22 SW8	5			- 3
		13	F14W03 SW9	5			- 3
		13	F14W05 SW11			6	
		13	F14W06 POS 6-1	5			- 3
		13	F14W02 POS 6-3	5			- 3
		4	LOAD SHED ROC RELAY	5			- 4
		345	BANK 1 FDR W83-89	3			
		345	ATTT-SS W83-W89 RT1	3			
		345	ATTT-SS W83-W89 RT2	3			
		345	BANK 2 FDR W84-90	3			
OSSINING	675						
		4	FEEDER 641			6	
MILLWOOD EAST	680						
		138	BUS 1	5			- 4
		138	BUS 2	5			- 4
MILLWOOD WEST	681						
		345	F W83 PRI BUS 2-4	4			- 4
		345	F W83 SEC BUS 2-4	4			- 4
		345	F W82 PRI BUS 8-10	4			- 4
		345	F W82 SEC BUS 8-10	4			- 4
		345	F W97 PRI BUS 10-12	4			- 6
		345	F W97 SEC BUS 10-12	4			- 6
		345	F W99 PRI BUS 14-16			6	
		345	F W99 SEC BUS 14-16			6	
		345	F W98 PRI BUS 16-18	4			- 6
		345	F W98 SEC BUS 16-18	4			- 6
		345	EAST SYN BUS BK TA			6	
		138	F 96961-96951 BUS 1W	3			
		345	ATTT-SS W82 RT1	4			- 1
		345	ATTT-SS W82 RT2	4			- 1
		345	ATTT-SS W83 RT1	3			
		345	ATTT-SS W83 RT2	3			

Figure H-7.–Monthly statuses of Con Edison trip tests and priority (PRI) statuses of components (from Con Edison Technical Services and Development Department).

LOCATION	CODE	VOLT.	EQUIPMENT PROTECTED	9/77	10/77	11/77	
MILLWOOD WEST 13KV	683						
		138	BANK 1			6	
		138	BANK 2			6	
		13	FDR 7W47 SW POS 11S	6			
MT KISCO	685						
		4	STATION L&P CUB 9	5			- 3
PEEKSKILL	690						
		13	FDR 13W81 CUB 8	5			- 2
		4	TRANSFER BUS CUB 12	5			- 2
		4	FDR 1345 CUB 17	5			- 3
		4	FDR 1346 CUB 19	5			- 2
BUCHANAN 13KV	694						
		13	SYN BUS	5			- 3
		13	NEUTRAL GRD BANK 2	5			- 3
		13	NEUTRAL GRD BANK 3	5			- 3
		13	FDR 13W81 POS F2-1	5			- 4
		13	F13W82 L&P1 POS F2-2	5			- 3
		13	FDR 13W92 POS F2-3	6			
		13	FDR 13W84 POS F2-5		6		
		13	FDR 13W85 POS F2-6	5			- 2
		13	FDR 13W87 POS F2-7	5			- 3
		13	L&P 2 POS LP2	5			- 4
BUCHANAN	695						
		138	FDR 95332 BUS SECT 4	5			- 5
		138	BANK 1	3			
		138	BANK 3	4			- 1
		138	BUS SEC 1	3			
		138	BUS SEC 3	5			- 5
		4	LOAD SHED ROC RELAY	5			- 4
BUCHANAN 345KV	696						
		345	F W96 PRI BUS 1-3	6			
		345	F W96 SEC BUS 1-3	6			
		345	F W98 PRI BUS 3-5	3			
		345	F W98 SEC BUS 3-5	3			
		345	F W97 PRI BUS 4-6	3			
		345	F W97 SEC BUS 4-6	3			
		345	ATTT-SS Y88	1			- 4/75
		345	F Y94 PRI BUS 7-11			6	
		345	F Y94 SEC BUS 7-11			6	
		345	F W93 PRI BUS 9-11			6	
		345	F W93 SEC BUS 9-11			6	
		345	ATTT-SS W93 RT1	6			
		345	ATTT-SS W93 RT2	6			
		345	BREAKER 1	3			
		345	BREAKER 3	3			
		345	BREAKER 5	3			
		345	BREAKER 6	3			
		345	BREAKER 7			6	
		345	BREAKER 9			6	
		345	BREAKER 11			6	
PLEASANT VALLEY	702						
		345	BANK SI- SOUTH BUS	4			- 1
		345	FEEDER 398	6			
		345	BREAKER RN2	6			
		345	BREAKER RNS2	6			
		345	BREAKER RS3			6	
		~~345~~	~~BREAKER RNS4~~	~~1~~			~~8/65~~
			COMPUTER ERROR APY				
BOXWOOD 106	794		NO TESTS REQUIRED AT THIS LOCATION				
SHAWNEE 103	797		NO TESTS REQUIRED AT THIS LOCATION				

Figure H-7 (continued).–Monthly statuses of Con Edison trip tests and priority (PRI) statuses of components (from Con Edison Technical Services and Development Department).

LOCATION	CODE	VOLT.	EQUIPMENT PROTECTED	9/77	10/77	11/77
ARDSLEY 1	801	NO TESTS REQUIRED AT THIS LOCATION				
NEPPERHAN 2	802	NO TESTS REQUIRED AT THIS LOCATION				
MANHATTAN PARK 3	803	NO TESTS REQUIRED AT THIS LOCATION				
GREENVILLE 4	804	NO TESTS REQUIRED AT THIS LOCATION				
DUNWOODIE 5	805	NO TESTS REQUIRED AT THIS LOCATION				
DOBBS FERRY 7	807	NO TESTS REQUIRED AT THIS LOCATION				
CRUGERS 8	808	NO TESTS REQUIRED AT THIS LOCATION				

Figure H-7 (concluded).–Monthly statuses of Con Edison trip tests and priority (PRI) statuses of components (from Con Edison Technical Services and Development Department).

Except where the relay cannot be removed from its substation housing or switchyard facility, relays are tested both in and out of their facility cabinet. Testing is always performed such that a minimum amount of protection is removed from service at any instant. Sample test reports are shown in figures H-8 to H-10.

If something is wrong with an electromechanical relay, the tester makes repairs in the field. If this cannot be done, a replacement unit is obtained from the warehouse, and the defective unit returned to the central laboratory for repairs. Static relays are calibrated in the field, but if any part is found defective, the component board is replaced and returned to central laboratory for repairs.

Instrumentation transformers[1] (current and potential) and circuit-breaker operating times are also tested. Corrections to circuit breaker maintenance are performed by the central substation group not in this department.

Following is an outline of the priority code shown in figures H-6 and H-7:

Priority	*Status*
6	Due for test
5	Due for test in 1 to 5 months
4	Due for test in 6 to 11 months
3	Overdue for test for 5 months or less
2	Overdue for test for 6 to 11 months
1	Overdue for test for 12 months or more

A priority of 4–2 indicates that the item has been priority 4 for two months.

[1]An instrumentation transformer is a transformer that is intended to reproduce in its secondary circuit, in a definite and known proportion suitable for use in measurements, control, or protective devices, the voltage or current of its primary circuit, with its phase relations substantially preserved.

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

RECORD OF RELAY TEST AT__________ ON__________ VOLT__________ NO.__________

RELAY NAMEPLATE DATA

PHASE	SERIAL NO.	TYPE	MFG	STYLE OR MODEL	VOLTS	CYCLES	SLOPE	NAMEPLATE RATIOS
A								C. T.
B		TAPS						
C		SCREW MARKINGS						C. T.

SPECIFIED SETTINGS

IMPEDANCE ELEMENT

CONTACTS ARE OPEN / CLOSED AT ZERO VOLTAGE AND CURRENT

ADJUST FOR__________VOLTS__________AMP.__________OHMS__________DEGREES LAG

TIME AT__________VOLTS__________AMP.__________DEGREES LAG

DETERMINE PICK-UP CURRENT AT__________VOLTS__________DEGREES LAG

DETERMINE PICK-UP CURRENT AT__________VOLTS__________DEGREES LAG

DETERMINE PICK-UP AND DROP-OUT VOLTAGE AT__________AMP.

OBTAIN PICK-UP CURRENT-VOLTAGE CURVE

DIRECTIONAL ELEMENT

CONTACTS ARE OPEN / CLOSED AT ZERO VOLTAGE AND CURRENT

TIME AT__________VOLTS__________AMP.__________DEGREES LAG

TIME AT__________VOLTS__________AMP.__________DEGREES LAG

DETERMINE PICK-UP CURRENT AT__________VOLTS__________DEGREES LAG

ADDITIONAL SETTINGS

TRIP TEST

	FOUND A	FOUND B	FOUND C	LEFT A	LEFT B	LEFT C
OIL CIRCUIT BREAKER TRIPS						
OPERATION IND. FUNCTION						
TYPE OIL CIRCUIT BREAKER						

RELAY STUD POTENTIALS

IMP.	VOLTS	DIR.	VOLTS
A		A	
B		B	
C		C	

INSTRUMENTS USED

AMMETER NO. __________

VOLTMETER NO. __________

C.T. TRANS. NO. __________

TIMER NO. __________

D-C. AUX. TIMER NO.

REMARKS

MECHANICAL INSPECTION

	Found	Left
Relay Properly Mounted	______	______
Minimum Contact Spacing	______In.	______In.
Plunger Move Freely	______	______
Contact Arms Tight on Shaft	______	______
Locking Screws Tight	______	______
Condition of Cover Gasket	______	______

Condition of:	Found	Left
Contacts	______	______
Bearings	______	______
Jewels	______	______
Pivots	______	______
Springs	______	______
Target	______	______

	Found	Left
Discs Tight on Shaft	______	______
Discs Centered	______	______
Discs Clear of Friction	______	______
Magnets Tight	______	______
Bearing Screws Tight	______	______
Tap Screws Tight	______	______

Tester __________ Date of Test __________ Job No. __________ Checked By __________

Helper __________ Reason for Test __________ Requisition No. __________ Approved By __________

TS 116

24M.397

Figure H-8.–Con Edison relay inspection data form.

CALIBRATION DATA

D-C. AUXILIARY TIMER CORRECTION FACTOR FOR   OPERATIONS   SECONDS

FOUND									LEFT								
Phase and Elem.	Tap	Screw	Volts	Amp.	Ohms	Deg. Lag	Time Ten Oper.	Time Ten Oper.	Phase and Elem.	Tap	Screw	Volts	Amp.	Ohms	Deg. Lag	Time Ten Oper.	Time Ten Oper.

Figure H-9.–Con Edison calibration data form.

C. E. CO. OF N. Y. INC.

RELAY TEST REPORT

STATION____________

EQUIPMENT____________ DATE____________

OVERCURRENT				GROUND		
PHASE	SERIAL NO.	M'F'R	TYPE	SERIAL NO.	M'F'R	TYPE
		TAPS OR TUBE MARKING			TAPS OR TUBE MARKING	

SPECIFIED SETTINGS

____ AMPERES MINIMUM ____ CONTACT SPACING	____ AMPERES MINIMUM ____ CONTACT SPACING
____ AMPERES ____ SECONDS	____ AMPERES ____ SECONDS
____ AMPERES ____ SECONDS	____ AMPERES ____ SECONDS
C.T. RATIO ____ P.T. RATIO ____	C.T. RATIO ____ P.T. RATIO ____

OVERCURRENT
FOUND SETTING

PHASE	TAP OR PLUNGER SETTING	LEVER SETTING	CONTACT SPACING	MINIMUM			INTERMEDIATE			TIME		
				AMPERES		TIME	AMPERES		TIME	AMPERES		TIME
				PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS

LEFT SETTING

AMPERES		TIME	AMPERES		TIME	AMPERES		TIME	AMPERES		TIME
PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS

GROUND

SETTING	TAP SETTING	LEVER SETTING	CONTACT SPACING	MINIMUM			INTERMEDIATE			TIME		
				AMPERES		TIME	AMPERES		TIME	AMPERES		TIME
				PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS
FOUND												
LEFT												

AMPERES		TIME	AMPERES		TIME	AMPERES		TIME	AMPERES		TIME
PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS	PRIMARY	SECONDARY	SECONDS

DIRECTIONAL ELEMENT SENSITIVITY TESTS

PHASE	AMPS.	VOLTS	TIME IN SECS.		PHASE	AMPS.	VOLTS	DISC. ACTION		FOR FILING
			FOUND	LEFT				FOUND	LEFT	
						40	0			SHEET NO.
						0				
						40	0			ITEM NO.
						0				
						40	0			
						0				

Figure H-10.–Con Edison test report form.

INSPECTION OF PROTECTIVE RELAYS	FOUND	LEFT
MECHANICAL CONDITION		
ELECTRICAL CONDITION		
POSITION OF TEST SWITCHES		
POSITION OF TEST LINKS		

CONDITIONS OF TEST	
C.T. CONTINUITY CHECK MADE	
C.T. IN CIRCUIT DURING TEST	
CURRENT INDICATORS CHECKED	
OPERATION INDICATORS FUNCTION	
AMBIENT TEMPERATURE	

INSPECTION OF AUXILIARY RELAYS

USE					
TYPE					
MECHANICAL CONDITION					
ELECTRICAL CONDITION					
SETTING					

TRIP TESTS

	FOUND				LEFT			
RELAY								
PHASE								
AUX. RELAY OPERATED *								
EQUIPMENT TRIPPED *								

NOTE:- IF TRIP TESTS ARE NOT MADE INDICATE REASON.

* SPECIFY AUX. RELAY THAT OPERATED AND EQUIPMENT THAT TRIPPED.

RELAY TESTS AFTER RESTORING EQUIPMENT TO SERVICE

POWER FLOW   AMPERES   KW. TO BUS—FROM BUS

PHASE	POSITION OF DIRECTIONAL CONTACTS	VOLTAGE READINGS: DIRECTIONAL ELEMENT (AT TEST LINKS)	VOLTAGE READINGS: IMPEDANCE ELEMENT (AT RELAY STUDS)	GROUND RELAY
				VOLTS
				MILLIAMPS

REMARKS:- REPORT IN DETAIL DEFECTS FOUND AND ADJUSTMENTS OR REPAIRS MADE

TEST ☐   INSPECTION ☐   REQUEST ☐   CHANGE SETTING ☐   INSTALLATION ☐

TECHNICIAN ______________ ASSISTANT ______________

CHECKED BY ______________ APPROVED BY ______________

17-19 (PAD) TECHNICAL SERVICES & DEV. 5/76

Figure H-10 (concluded).–Con Edison test report form.

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Appendix I

CON EDISON SYSTEM AND NEW YORK POWER POOL OPERATING PROCEDURES RELATED TO EMERGENCY OPERATIONS

Normal operating procedures attempt to provide adequate power generation and transmission reserve capability to cover any reasonably anticipated system disturbance. Should this reserve decline and the system involved be unable to increase the operating reserve or decrease transmission-line overloads for any reason, then preplanned emergency operating procedures are provided for power-system operators to maintain security of the system and to minimize and localize interruptions.

Con Edison promulgates departmental orders of the System Operations Department, which include emergency operating procedures, thunderstorm procedures,[1] load-reduction procedures, updated load-reduction capability through periodic updating procedures, and procedures for informing the public and Federal and State authorities.

Both the Northeast Power Coordinating Council (NPCC) and the New York Power Pool (NYPP)[2] have established guides that set forth the objectives, principles, and requirements, and load-relief procedures in a major emergency, such as unusually low frequency (capacity deficiency), equipment overload, or low voltage, which might seriously affect the operation of the bulk-power-supply systems. These guides are nearly identical. The objectives are—

(1) To minimize the effect on customer service

(2) To restore the balance between load and generation in the shortest practical time

(3) To minimize the risk of damage to transmission and generating facilities, to distribution equipment, and to customer's utilization equipment

The North American Power Systems Interconnection Committee's (NAPSIC's)[3] Operating Guide No. 9, Action in Emergency, attempts to provide interconnected systems with a uniform understanding and approach to the problem of a capacity shortage. This guide states that for a capacity shortage causing an overloaded tie between interconnected systems that cannot be relieved by adjusting generation, relief measures must be applied to within emergency limits. If a neighboring system is experiencing an overload on a tie toward the deficient system, and after immediate relief is requested, the neighboring system may open the overloaded ties if the intolerable overload continues.

OPERATING RESERVE

The required amount of operating reserve and its distribution must be carefully evaluated within each system. Factors involved in determining the magnitude of these reserves include the size of the largest unit, generation forced-outage rates, load-forecast errors, geographical distribution of generation resources, the response characteristics of generation resources, transmission capability, the capability and distribution of interconnections, and the availability of interruptible loads, including pumping loads on pumped storage generation.

NAPSIC's Operating Guide No. 10, Reserve Capacity, states, "Spinning reserve capacity available to any coordinated area shall be sufficient to meet its largest instantaneous hazard without unduly jeopardizing other coordinated areas' reliability of operations." However, the actual details of operating reserve policy for NPCC and NYPP is quite extensive and is further augmented by Con Edison's own operating orders.

NPCC adopted in March 1972 and revised in September 1976 a general operating reserve policy applicable to all members in the four areas composing the region: NYPP and the New England Power Pool (NEPOOL), in the United States, and the Ontario Hydro and the New Brunswick systems, in Canada. The NPCC operating reserve policy establishes minimum requirements governing the amount, availability, and distribution of operating reserve. The policy includes procedures for corrective action and mutual assistance in case of operating reserve shortages.

Operating reserve is defined by NPCC as the sum of 10- and 30-minute reserves. The 10-minute reserve is the sum of synchronized reserve (generating capacity that is

[1]These procedures were developed after July 13, 1977.
[2]See appendix C for discussion of NPCC and of NYPP.
[3]See appendix C for discussion of NAPSIC.

on line and ready to pick up load and capacity that is made available by dropping reversible pumped-storage hydro units in the pumping mode) and nonsynchronized reserve (generating capacity available for synchronizing and load curtailment under control of the system dispatcher).

The 10-minute reserve is designed to cover the capacity loss from the most severe first contingency, and the 30-minute reserve is designed to cover one-half the capacity loss from the next most severe contingency.[4]

The NYPP Operating Policy No. 2-7 (OP-2-7), Operating Reserve Policy, subscribes to the NPCC minimum requirements. NYPP, as well as NPCC, further promulgate minimum requirements for synchronized reserve on automatic generation control (AGC) that is necessary to provide adequate control area regulation. Adequate regulation can reduce the cumulative inadvertent difference between scheduled and actual interchange power flow with other control areas. AGC has the further advantage of raising the output of synchronized generation without operator intervention should there be a loss of generation within NYPP. No generating units within Con Edison's system were assigned to AGC at the time of the July 13 disturbance.

Operating procedures are listed in NYPP's OP-2-7, which provides direction to the senior pool dispatcher and the member companies on means to maintain the pool's minimum operating reserve requirement as well as each company's operating reserve obligation to the pool. If the 10-minute reserve requirement cannot be met, the procedures call for conversion of the 30-minute reserve to 10-minute reserve. Should the 10-minute reserve still be less than the 10-minute reserve requirement after all attempts to acquire it from NYPP members and other neighboring pools have been exhausted, then OP-3-0, Voltage Reduction Policy, is put into effect.

VOLTAGE REDUCTION

NYPP's OP-3-0, Voltage Reduction Policy, is implemented by the senior pool dispatcher and directs the deficient member under the recited conditions to reduce voltage by as much as 5 percent. If this is not sufficient, other members would be directed to reduce voltage by as much as 5 percent. Also, other neighboring systems may be requested to provide assistance by way of voltage reductions so that emergency energy may be transferred to NYPP. The surrounding systems will generally assist NYPP in preventing interruption of firm customer load if NYPP is already in voltage reduction.

If the load-capacity imbalance or insufficient operating reserve is forecast far enough in advance, then NYPP can institute OP-7-2, Load Curtailment Policy. The senior pool dispatcher, upon determining that voltage reduction will not provide a sufficient capability margin to continue to supply NYPP, will direct member companies to curtail company use wherever possible, contact large industrial and commercial customers and ask for voluntary curtailment of load, and as a final voluntary measure, make general radio and television appeals to the public to restrict unnecessary use.

The NYPP operating policies, described in this and the preceding sections, attempt to—

(1) Insure that operating capacity is available to meet forecast load, including allowance for error

(2) Provide reasonable protection against equipment failure

(3) Provide adequate regulation of scheduled power interchange

The procedures previously outlined generally assume that the loss of operating reserve is gradual and that there is time available to take a number of preventive measures to avoid the prospect of load exceeding available operating capacity without actually involuntarily curtailing customer load. These procedures can be classified as normal operating procedures before an emergency.

NYPP EMERGENCY PROCEDURES

The NYPP guide for emergency operations is given in OP-1-2 and includes the following:

(1) Tie lines, including internal transmission circuits, should not be opened deliberately except to prevent sustained interruption to customers' service or to prevent damage either to these tie lines or to equipment due to overloads, extreme voltages, or extreme frequencies.

(2) A sustained frequency excursion of ± 0.2 Hz is an indication of major load-generation unbalance. It is important for the trouble area to provide load-generation balance at once to restore frequency so that any separated areas may be reparalleled as soon as possible.

(3) As a general rule, load relief[5] based on frequency alone risks undesirable overloading or tripping of tie lines or internal transmission circuits. If frequency is decreasing rapidly, these risks are preferred to the risk of widespread shutdowns.

(4) At some low frequency, the ability of the generators to maintain output is endangered. Although some machines will operate safely below 58.5 Hz, for

[4]NPCC defines first-contingency loss as the largest capacity including any assigned 10-minute reserve that would result from the loss of a single generator, circuit, transformer, or bus section and second-contingency loss as the largest capacity outage that would result from the loss of a single generator, circuit, transformer, or bus section after allowing for the first-contingency loss.

[5]Load relief is defined as the load reduction accomplished by reducing voltage, by shedding load (interruption of customer load), or both.

the sake of uniformity the cutoff frequency 58.5 Hz has been selected for the last step in the emergency load-relief procedure. It is recognized, however, that some machines may be in danger above 58.5 Hz. If a machine is tripped above 58.5 Hz, equivalent load relief must be provided.

NYPP further requires the following:

(1) Accurate and reliable metering of tie line loadings and system frequency should be available at each dispatch center.

(2) Reliable and immediately available communication channels should exist between the dispatchers of adjacent power systems.

(3) Each dispatcher should know the permissible emergency loading of each of his tie lines and transmission circuits that can be used for at least 15 minutes. The settings of the relays on the tie lines must exceed this value.

(4) Each system must provide a means to shed a minimum of 25 percent of its system load automatically to protect against low-frequency conditions and a minimum of 50 percent of its system load manually to protect against low-voltage and overload conditions. The automatic portion, if also controlled by manual means, may be included as part of the 50 percent manual relief.

(5) All automatic generation control must be removed from service at 59.8 Hz on frequency decline and 60.2 Hz on frequency increase.

NYPP's emergency load-relief procedure in the event of tie-line overload is in agreement with NAPSIC's Operating Guide No. 9, discussed earlier. It requires establishment of communication with the operator of the system producing the overload. An effort is to be made to have overload reduced from the source. If after a reasonable time based on amount of overload, improvement is not made, ties are to be opened as necessary to prevent damage to equipment. One obvious means to reduce overload from the source (deficient system) is for the source to provide some load relief (shed load).

NYPP's emergency load-relief procedure in the event of deteriorating or low-frequency condition is in agreement with NAPSIC's Operating Guide No. 11, Load Shedding, Sectionalizing, and Restoration. The NYPP recommended operator and automatic actions and dependent on the conditions associated with the frequency condition. When the generation-deficient area is clearly identifiable, when the frequency decline is slow enough to permit communication among various system operators, and when adequate consideration can be given to the amount of assistance that can be delivered to the deficient area by all power systems, the following procedure will apply. The deficient system will initiate the following immediate action to correct load-generation unbalance: load-generation unbalance:

Frequency (Hz)	*Action*
59.5 to 59.0	10-percent load relief, if the loads on tie lines permit.
59.0 to 58.5	An additional 15-percent load relief, (25 percent, total) if the loads on tie lines permit.
58.5	If frequency is still declining, all necessary steps are to be taken, including separating units, to prevent damage to equipment and to minimize service interruptions.

When the generation-deficient area is not clearly identifiable, and when the frequency decline is so rapid that it precludes analysis and communication among various system operators, the previously outlined procedure will apply without regard to tie-line loadings. In addition, automatic facilities are to be provided to achieve the results shown above for frequency ranges of 59.5 to 59.0 Hz.

NYPP's and its member companies' automatic load-shedding program is shown in table I-1, where the percentage load drops at the various underfrequency settings are based on the 1976 peak loads on each

Table I-1.—*Portion of Automatic Load Shedding at Various Frequencies by Members of New York Power Pool*

Member	Load shed (percent) by frequency (Hz)						
	59.5	59.3	58.8	58.3	58.0	57.8	Total
Central Hudson Gas and Electric Corp. and Orange & Rockland Utilities, Inc.	–	11.4	14.6	–	–	–	26.0
Con Edison	[1]5.1	8.4	11.6	9.2	–	14.7	48.8
Long Island Lighting Co.	–	10.2	15.4	–	6.3	–	31.9
New York State Electric & Gas Corp.	–	10.0	14.6	–	–	–	24.6
Niagara Mohawk Power Corp.	–	14.3	15.6	–	–	–	39.9
Power Authority of the State of New York	–	5.7	7.5	–	–	–	13.2
Rochester Gas & Electric	–	10.0	16.2	–	–	–	26.2
All New York Power Pool	1.77	10.17	13.56	3.15	.91	5.06	34.62

[1] Automatic voltage reduction of 8 percent with 8-second delay.

company. The 1976 percentages were used to determine the approximate percentage for NYPP. These percentages conform to OP-1-2, previously discussed, and are comparable with the automatic load-shedding practice in other regional reliability councils and their subregions shown in table I-2.

CON EDISON'S EMERGENCY PROCEDURES

Con Edison emergency planning to cover the emergency actions previously described is contained in System Operator Department Order E-60-6, entitled "Procedure for Action When Generating Reserve Capacity Is at or Below Critical Level." It was last revised on June 1, 1977. The steps that Con Edison has planned to meet certain types of situations, including prospective capacity deficiency, slowly deteriorating frequency, and major emergency, are reviewed in the material that follows.

Capacity Deficiency

When all sources for supplemental power from NYPP and from other pools have been exhausted and a capacity reserve deficiency is still in prospect, the Con Edison plans call for initiation of a sequence of actions. The procedures are governed by the following principles:

(1) The basic integrity of the system must be maintained.

(2) If the probability of implementing steps beyond 5-percent voltage reduction or more severe load curtailment is *high*, the public should be made aware of the situation and their help should be requested.

(3) If the probability of implementing steps beyond 5-percent voltage reduction is *low*, the public need not be aware of the situation.

When by early morning the system operator finds that the daily reserve at forecast peak load is such that one or more of the procedures in System Operator Department Order E-60-6 will be necessary, he must declare the most likely extent of the load relief required. This allows time for notification of the proper authorities.

The load relief measures available to and planned for use by Con Edison are—

(1) *Use of leased steam plants*—some of Con Edison's customers can use steam boilers to cut down on the company's steam-system load from boilers used also for generation. The company anticipates 25 MW relief after an elapsed time of 3 hours.

(2) *Import of extraordinary supplemental power*—Con Edison would attempt to import any additional power from any source even if the loss of a double-circuit 345-kV tie line would risk having other tie flows above emergency ratings. This power could be available in a short time.

(3) *Curtailment of load on company facilities*—Con Edison would reduce all unessential loads on their own properties such as office air conditioning and warehouse lighting. The company anticipates 35 MW of relief available for 15 minutes to 2 hours.

(4) *Request to all members of NYPP to prepare for voltage reduction*—if transmission capability will permit, and if voltage reduction measures are likely, Con Edison will request that pool members prepare for voltage reduction, because some NYPP systems would require significant time before actually performing voltage reduction. The pool can request other members to reduce voltage by as much as 5 percent.

(5) *Request to large customers to reduce load as much as possible*—Con Edison estimates between 150 and 200 MW of relief could be available within 1 to 2 hours.

(6) *Public appeal to all customers to reduce all power consumption as much as possible*—Con Edison estimates between 150 and 200 MW relief could be available within 2 to 4 hours.

(7) *Institution of 3-percent voltage reduction*—a 3-percent voltage reduction can be performed in less than 5 minutes from the energy control center providing about 163 MW of relief, based on a summer peak of 8,600 MW. Con Edison would request all NYPP members to reduce voltage if there is no transmission limitation on the resulting power made available to Con Edison.

(8) *Institution of further voltage reduction to 5 percent*—an additional 109 MW of relief, based on a summer peak of 8,600 MW, can be performed in less than 5 minutes from the energy control center.

(9) *Request for emergency hydro generation from The State of New York Power Authority (PASNY)*—if transmission capability will permit, Con Edison would request PASNY to make about 50 MW of additional hydro generation by emergency release of Lake Ontario water. This could be available within 15 to 20 minutes.

(10) *Institution of further voltage reduction to 8 percent*—an additional 163 MW of relief, based on a summer peak of 8,600 MW, can be performed in less than 5 minutes from the energy control center. This totals to 435 MW of load relief through voltage reduction controlled from the center. Although not stated in System Operator Department Order E-60-6, Con Edison can also reduce voltage at some generating stations that serve load directly in 3-, 5-, and 8-percent steps, totalling 90 MW of additional relief, and manually at some substations, totalling 45 MW of additional relief. However, this additional load reduction cannot be controlled directly from the energy

Table I-2.—*Automatic Load Shedding by Frequency and by Regional Councils and Subgroups*

National Electric Reliability Council Regional Council	Summer 1977 load		Load shed (percent) by frequency (Hz)																		Region and subregion load shed (percent)	Continental United States load shed (percent)
	(MW)	(percent)	59.6	59.5	59.3	59.2	59.1	59.0	58.9	58.8	58.7	58.6	58.5	58.3	58.1	58.0	57.8	57.6	57.5	57.0		
East Central Area Reliability Coordination Agreement	59,838	14.94	–	–	10.0	–	–	–	15.0	–	–	–	–	–	–	–	–	–	–	–	25.0	3.735
Electric Reliability Council of Texas	27,582	6.89	–	–	5.0	–	–	–	10.0	–	–	–	10.0	–	–	–	–	–	–	–	25.0	1.723
Mid-Atlantic Area Council	32,650	8.15	–	–	10.0	–	–	–	10.0	–	–	–	10.0	–	–	–	–	–	–	–	30.0	2.445
Mid-America Interpool Network	33,663	8.40	–	–	10.0	–	–	10.0	–	–	10.0	–	–	–	–	–	–	–	–	–	30.0	2.52
Mid-Continental Area Reliability Coordination Agreement	17,664	4.41	–	–	10.5	–	–	9.9	–	–	10.2	–	–	–	–	–	–	–	–	–	30.6	1.349
Northeast Power Coordinating Council:																						
New York Power Pool	21,590	5.39	–	1.77	10.17	–	–	–	–	13.56	–	–	–	3.15	–	.91	5.06	–	–	–	34.62	1.866
New England Power Exchange	13,905	3.47	–	–	11.28	–	–	–	–	15.07	–	–	–	–	–	–	–	–	–	–	26.35	.914
Total	35,495	8.86	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Southwest Power Pool	37,090	9.26	–	–	10.0	–	–	10.0	–	–	10.0	–	–	–	–	–	–	–	–	–	30.0	2.778
Southeastern Electric Reliability Council:																						
Florida Subregion	15,681	3.92	–	–	–	14.6	14.6	14.6	–	14.6	14.6	23.6	23.6	–	–	–	–	–	–	–	52.8	2.070
Southern Companies Subregion	19,946	4.98	–	10.0	–	10.0	–	–	–	10.0	–	–	–	–	–	–	–	–	–	–	30.0	1.494
Tennessee Valley Subregion	20,150	5.03	–	12.8	1.7	26.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	41.0	2.062
Virginia-Carolinas Subregion	26,245	6.55	–	–	10.0	–	–	10.0	–	–	–	–	10.0	–	–	–	–	–	–	–	30.0	1.965
Total	82,022	20.48	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Western Systems Coordinating Council:																						
Northwest Power Pool (United States only)	28,987	7.24	–	1.5	1.5	1.5	1.5	14.8	14.8	14.8	14.8	14.8	13.8	13.8	13.8	11.5	11.5	11.5	10.6	10.6	52.2	3.78
Rocky Mountain Power Area	4,276	1.07	.5	5.9	5.9	5.9	5.9	10.7	10.7	10.7	10.7	10.7	12.1	12.1	12.1	14.0	14.0	14.0	.3	.3	43.3	.47
Arizona and New Mexico	6,871	1.78	.6	–	–	–	–	22.4	22.4	22.4	22.4	22.4	23.5	23.5	23.5	19.1	19.1	19.1	5.7	5.7	71.30	1.23
Southern California and southern Nevada	18,129	4.53	–	10.4	10.4	10.4	10.4	23.8	23.8	23.8	23.8	23.8	24.8	24.8	24.8	9.8	9.8	9.8	1.8	1.8	70.60	3.20
Northern California and northern Nevada	16,039	4.00	.5	9.1	9.1	9.1	9.1	20.2	20.2	20.2	20.2	20.2	20.7	20.7	20.7	.1	.1	.1	.7	.7	51.3	2.05
Nonpool	216	.03	–	–	–	–	–	5.1	5.1	5.1	5.1	5.1	4.6	4.6	4.6	5.1	5.1	5.1	–	–	14.8	.01
Total	74,518	18.61	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	400,522	100.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	35.65

control center. Table I-3 shows all the voltage-reduction levels and associated megawatt reductions for each of the six service districts as of June 2, 1977, all based on a summer peak of 8,600 megawatts.

(11) *Request for traction customers to cut off heat*—in the heating season, approximately 30 to 70 MW of relief could be achieved within about 2 hours.

(12) *Manual load shedding*—radially fed or nonnetwork-supplied load would be manually shed first from the load-shedding console of the energy control center. Networks would be shed next depending on the need. If the need for manual load shedding is known far enough in advance, the interruptions to the customers can be planned to be spread around the service area such that each customer would not be without service for more than one hour, thereby minimizing customer inconvenience. This system is designed to enable a total of 1,707 MW load to be shed in less than 5 minutes. Shown in table I-4 are the manual load shedding increments for the six service districts as of June 2, 1977, all based on a summer peak of 8,600 MW. As a final measure, Con Edison would request the railroads and the transit authority to start series operation only on weekends and after normal hours. Series operation reduces the acceleration capability of rail transit and hence reduces the electric demand. This could provide about 195 MW of relief in 15 to 20 minutes.

Slow Decline in Interconnected System Frequency

Con Edison is part of the Eastern Interconnected System, which extends from New England west to the Rocky Mountains. As long as Con Edison remains synchronized with this interconnected system, the system frequency is not likely to decline to the first step of underfrequency load shedding, because this would require a frequency decline in the entire interconnected system. However, if Con Edison should become a part of a smaller isolated area for any reason, the probability is increased that there will be a load greater than existing online generation with resultant frequency decline. In this case, Con Edison would drop either manually or automatically some related loads at specific low-frequency points. Table I-4 shows the amounts of load that could be shed in accordance with the Con Edison plan at various frequencies.

Major Emergency

Con Edison has established order No. EO-4032-7, Guide for Action in Major Emergencies Affecting Electric System Capability, dated June 8, 1973. A major emergency differs somewhat from the assumed conditions and operating procedures previously discussed in that it usually requires immediate action. Under some circumstances, such as (1) line overloads that substantially exceed emergency ratings, (2) abnormally low bus voltage, and (3) abnormally low system frequency, customer load must be shed to prevent loss of the entire system or to prevent damage to equipment, which would result in extensive delay in service restoration. As stated by Con Edison:

> During a system emergency, a prolonged attempt to avoid any interruption of service to customers may result in damage to Company and Customers' equipment followed by a prolonged interruption affecting a large number of customers. Under such circumstances, reducing load or deliberately dropping a part of the load and maintaining reasonably normal service to the remainder will avoid damage to equipment and may reduce considerably the number of customers affected and hasten the restoration of normal service.

Con Edison's plan for load relief in a major emergency is stated in its order No. EO-4036-7 as follows:

> The fundamental plan of operation in case of overloaded tie feeders, abnormally low bus voltage or abnormally low frequency is for the area in trouble to perform the necessary operations to restore conditions to normal as rapidly as possible. Provision is made for the sending area or system to trip the tie feeders leading to the area in trouble if conditions have not been relieved in time.
>
> The bus voltage or the frequency may decrease slowly or relatively rapidly. Where time is available, normal methods of correcting the condition may be effective. However, a rapid decrease in bus voltage

Table I-3.—*Load Reduction Available to Con Edison System for Manual Voltage Reduction, by Service District*

Service district	Load reduction (MW) by place of control and voltage reduction (percent): Energy control center			Generating stations[1]			Substations[1]		
	3	5	8	3	5	8	3	5	8
Manhattan	91	153	244	10	17	27	–	–	–
Bronx	14	21	35	10	16	26	–	–	–
Brooklyn	26	46	72	14	23	37	–	–	–
Queens	30	50	80	–	–	–	2	5	7
Westchester	1	1	2	–	–	–	12	20	32
Staten Island	1	1	2	–	–	–	2	4	6
Total	163	272	[2]435	34	56	90	16	29	45

[1] These stations and substations are not directly controlled from energy control center.
[2] If the system frequency declines below 59.5 Hz, automatic voltage reduction of 8 percent occurs.

Table I-4.—*Load Reduction in Con Edison System From Automatic Load-Shedding Measures, by Frequency and by Service District*

Frequency (Hz)	Load reduction (MW) by service district								Portion of 8,600-MW peak (percent)
	Manhattan	Bronx	Brooklyn	Queens	Westchester	Staten Island	Total	Cumulative total	
59.5	244	35	72	80	2	2	435	435	5.1
59.3	–	43	73	–	330	65	711	1,146	13.3
58.8	–	–	141	486	307	62	996	2,142	24.9
58.3	–	240	554	–	–	–	794	2,936	34.1
57.8	1,117	146	–	–	–	–	1,263	4,199	48.8

or frequency will not permit the time required for normal corrective methods and load reductions must be initiated promptly.

Stations in Trouble

The following methods are applicable in correcting one or more of the above abnormal situations:

a. Adjust phase-angle control.
b. Check that shunt reactors are disconnected and capacitors are connected.
c. Start, synchronize and load additional generating capacity if time permits.
d. Lowering bus voltage
   (1) Automatically via underfrequency relays (8% @ 59.5 Hz.)
   (2) Manually
      (a) Locally at the station
      (b) Remotely from West End Ave. (Energy Control Center)
e. Disconnect load
   (1) Automatically via underfrequency relays
   (2) Manually
      (a) Locally at the station
      (b) Remotely from West End Ave. (Energy Control Center)
f. Request for voluntary reduction of electric usage by large customers.
g. Request Railroads and Transit Authority to start series operation. (Only on weekends or between 8:00 P.M. and 6:00 A.M. on weekends.)

Reduction of bus voltage will reduce the bus load and will also reduce the tie feeder loading if the load power factor is not too low. With low load power factor a reduction in bus voltage will reduce the bus load but may transfer reactive Kva from the generators to the tie feeders and result in an increase in the tie feeder ampere loading. If the first step of voltage reduction increases the feeder loading, this method of load relief should be discontinued. Tests indicate that a 1% reduction of bus voltage will result in about a 1% reduction in load (kW).

If normal means of restoring voltage and frequency are not available or if the frequency is dropping too fast, the only effective method of correcting low bus voltage or low frequency is to immediately disconnect one or more blocks of distribution load, as required, to restore the voltage and frequency to safe values.

Stations Not in Trouble

If tie feeder overloads have not been relieved within the specified time, the operators in stations which are not in trouble are expected to relieve the overload by opening the breakers on all tie feeders to the station or area in trouble, after consultation with the System Operator, if possible.

Load Reduction

Each year Con Edison assesses its load-reduction program. This is partly because the load-reduction program may need modifications as the system load changes so as to continue to meet the NPCC's load-reduction criteria discussed earlier. The Con Edison automatic and manual load-reduction program for the summer of 1977 was issued June 2, 1977, after the annual review. Summary tabulations indicating amounts in the load-reduction program were given earlier in tables I-3 and I-4.

Con Edison has issued order No. EO-2004-1, Procedure for Updating Load Reduction and Load Restoration Program, dated March 28, 1972. In this procedure the 4-kV electric feeders that supply essential-service customers are exempt from the load-shedding program. Essential services include the following:

(1) Airports
(2) Bridges
(3) Gas utility companies
(4) Fire department communication centers
(5) Gas pressure recording stations
(6) Hospitals
(7) Police department communication centers
(8) Police precincts
(9) Prisons
(10) Sewage treatment plants
(11) Sewage pumping stations
(12) Water pumping stations

Con Edison has also issued order No. EO-4061-1, List of Essential Services To Be Maintained During 4 kV Load Shedding, dated June 14, 1977. This list contains the name and address of the customer as well as the 4-kV feeder that is exempt from the load shedding.

Automatic Load Shedding

NPCC has established policy that requires that each member system provide the necessary facilities to shed a minimum of 25 percent of its load automatically and a means to relieve at least 50 percent of its load manually within 10 minutes. The NPCC System Protection Task

Force suggests that underfrequency relays be set to shed 10 percent of load when the frequency declines to 59.3 Hz and an additional 15 percent when the frequency declines to 58.8 Hz.

Con Edison has both automatic and manual load-shedding capability. Automatic underfrequency load shedding is designed to operate in electrical islanding situations where there is a generation deficiency and a substantial decline in frequency. Manual load shedding is an operating function that is intended for use when contingencies occur that exceed possible-but-improbable design but before system separation or islanding occurs. Con Edison has about 48.6 percent of its load relayed for automatic underfrequency load shedding. Table I-5 lists the steps of Con Edison's automatic load shedding program and the amount of load, in percent of its 1976 peak load, to be shed at each step.

Table I-5.—*Steps in Con Edison Load-Shedding Program by Frequency Levels*

Frequency (Hz)	Average commit time (cycles)	Relay time delay (cycles)	Load shed (percent)
59.5	[1]	[1]	[2] 5.1
59.3	34	32	[2] 8.1
58.8	34	32	[2] 4.7
58.8	34	10	[2] 7.0
58.3	38	9	9.1
57.8	29	9	14.6
Total	–	–	48.6

[1] Load reduction of 5.1 percent is accomplished by automatic voltage reduction. Time required for the voltage reduction is 8 seconds.

[2] Can also be shed manually.

Appendix J

RESTORATION CHRONOLOGY, OR SEQUENCE OF EVENTS

This account is annotated and abridged from Con Edison preliminary data.

Time	*Event*
p.m.	
9:36	Total system shutdown
10:12	Narrows gas turbine (GT) generating unit 2-1 placed on line into Greenwood
10:13	Narrows GT 2-1 tripped
10:14	Narrows GT 2-2 placed on line into Greenwood and tripped
10:15	Narrows GT 2-2 placed on line into Greenwood
10:16	Narrows GT 2-2 tripped
10:25	Pleasant Valley transformer 1 energized from 115-kV bus
10:27	Line W93/W79 (Buchanan to Eastview to Sprain Brook) energized momentarily and tripped automatically (auto)
	Line Y88 energized, Ladentown to Buchanan South
10:29	Line 901, Valley Stream to Jamaica, energized from Valley Stream and tripped
10:32	Line W97 (Buchanan South to Millwood West) reported energized momentarily and then deenergized
	Bowline Point No. 1 tripped auto
10:33	Circuit 18002 (Corona to Jamaica) energized momentarily and deenergized
	Circuit 42232 (Gowanus to Greenwood) energized momentarily to Greenwood and deenergized
	Greenwood to Vernon circuits 31231 and 31232 energized momentarily to Vernon and deenergized
	Breaker No. 6 at Buchanan closed and manually tripped by station operator; 345-kV transformer TA5 faulted and on fire
10:36	Lines 80 and W81 to Millwood West energized at Pleasant Valley; line W81 tripped at Pleasant Valley but energized from Millwood via line 80
10:37	Leeds/Pleasant Valley circuit 92 opened auto; lines 80 and W81 deenergized

Time	*Event*
p.m.	
10:38	Line 18002 tripped at Corona
	Line 34183 tripped at Corona
	Bus tie breaker W tripped at 179th Street
10:40	Line W97 (Buchanan/Millwood West) energized momentarily and then deenergized
10:43	Line Y94 (Ramapo/Buchanan North) opened at Ramapo
	Astoria feeders 34183 and 34123R bus breakers tripped auto, feeders deenergized; Astoria bus section 2E lightning arrestor ruptured
10:48	138-kV feeder 16 (Pleasant Valley to Carmel) energized to Carmel
11:06	Feeder 11 energized at Pleasant Valley
11:20	Line 92 closed at Pleasant Valley, energized from Leeds
11:22	Transformer S1 closed at Pleasant Valley (345- and 138-kV sides connected)
11:30	Circuit 901 energized at Valley Stream
	Line W97 energized at Buchanan South into Millwood West; Y88, continuous to Ladentown
11:40	Circuit 901 closed in at Jamaica, from Valley Stream
11:45	Circuit 42232 energized to Greenwood from Gowanus GT 1
11:53	Line W82/W65 energized at Millwood West to Eastview and Sprain Brook
	Circuit 42232 opened at Gowanus
11:55	Circuit 18001 energized at Jamaica to Corona
a.m.	
12:05	Attempt to synchronize Astoria GT 4-1; unit tripped auto
12:10	Circuit 34183 Corona to Astoria East energized momentarily and tripped auto
	Circuit 42232 energized to Greenwood from Gowanus GT1; circuit 38312 to Bensonhurst energized
12:13	Line Y94 energized at Ramapo to Buchanan North

Time a.m.	Event
12:14	Circuit 42231 energized to Greenwood from Gowanus GT
12:15	Attempt to synchronize Astoria GT 4-1; unit tripped auto
12:21	Feeder 23162 (Narrows to Greenwood) and circuit 31232 (Greenwood to Vernon) energized
12:23	Circuit 34185 (Corona to Astoria East) energized to Astoria
12:27	Circuits 42232, 38B12, 31232, and 23162 deenergized
12:30	Line W93/W79 energized from Buchanan to Eastview and Sprain Brook
	74th Street GT failed to start because of low battery voltage
12:35	Circuit 34111 (Astoria East to North Queens) energized to North Queens
	Circuits 34112, 12111, and 12112 (North Queens to Astoria) energized
12:47	59th Street GT 2 tripped auto via reverse power
1:00	Circuit 9825 energized from Mohansic to Millwood East
	Circuit 42231 deenergized
1:05	Circuits 34182 (Corona to Astoria East) and 34129 (Astoria GT) energized
1:15	Circuits 42422, 42424, and 42231 energized from Gowanus GT
1:16	Astoria East Breaker 4W closed, energizing circuits 34051 and 34052 to Hell Gate; 34123 to Astoria No. 3; 34124L&M to Astoria unit No. 4; 34125M to Astoria unit No. 5; 34181, 34184, and 34186 to Corona; 15031 and 15032 (179th Street to Sherman Creek); 15051, 15052, 15053, and 15054 (Hell Gate to 179th Street); 179th Street transformer and yard feeders; 38X01, 38X02, 38X03, and 38X04 (179th Street to Tremont); 99151 and 99152 (179th Street to Dunwoodie); transformers at Parkchester/Tremont and Sherman Creek; 99032 (Sherman Creek to Dunwoodie); 38W05, 38W06, 38W07, and 38W08 (Dunwoodie to Granite Hill); 99,942 (Dunwoodie to Sprain Brook); 38W04, 38W09; and 38W10 (Dunwoodie to Washington Station); and 99141 (Dunwoodie to Sprain Brook)
1:17	Gowanus GT 4-3 on bus to circuit 42424
1:22	Astoria GT feeder 34129 and units 4-1 and 4-2 tripped automatically
1:25	Circuit 34125M (Astoria East to Astoria 5) deenergized; Hell Gate to 179th Street feeders 15053 and 15054—potheads ruptured; circuits 34051, 34052, 34123K, 34134L, 34181, 34182, 15031, 15032, 15051, 15052, 15053, 15054, 15151, 15153, 15155, 15158, 15159, 38X01, 38X02, 38X03, 38X04, 99151, 99152, 99032, 38W05, 38W06, 38W07, 38W08, 99942, 99997, 38W04, 38W09, and 38W10 tripped auto and were deenergized
1:30	Narrows feeders 23162 isolated; lightning arrestor damaged
1:32	Circuit 212 energized at Waterside 1 to Waterside 2
1:33	Circuits 814 and 815 energized at 59th Street into Waterside 25-Hz bus and Waterside 1
	Circuit W84/W90 energized at Millwood West into Pleasantville and Dunwoodie
	Circuit W74 energized at Dunwoodie to Dunwoodie North
1:35	Circuit 42231 closed at Greenwood, energized from Gowanus (GTs on)
	Narrows GT 2-2 on line, energizing Greenwood feeder 23162
1:37	Narrows GT 2-2, tripped via reactive power; circuit 23162 deenergized
	Circuit W84/W90 opened at Millwood West
	Circuit W74 opened at Dunwoodie
1:39	Narrows GT 2-3 on line; circuit 21362 energized
1:41	Narrows GT 2-3 tripped auto via reactive power; circuit 23162 deenergized
1:42	Line W84/W90 energized at Millwood West to Pleasantville and Dunwoodie
	Line W74 energized at Dunwoodie to Dunwoodie North
	Narrows GT 2-1 on line, energizing circuit 23162; tripped auto; lightning arrestor flashed over on barge 2
1:45	Circuit 141 energized at Waterside 1 to East River
1:46	Circuit 142 energized at Waterside 1 to East River
1:49	Line W83/W89 energized at Millwood West to Pleasantville and Dunwoodie
	Line W73 energized at Dunwoodie to Dunwoodie South
1:50	Circuits 9825 and 9826 energized at Millwood East from Carmel and Mohansic
	Circuit 96961 energized at Millwood East to Millwood West
	Circuit 96951 energized at Millwood West to Buchanan
	Circuit 145 energized at Waterside 1 to East River
	Dunwoodie 345-kV feeder Y50 potheads ruptured

Time a.m.	Event
1:50	59th Street GT 1 tripped auto via reverse power
1:51	Waterside GT 1 tripped auto; battery lead burned off
1:52	Circuit 244 energized at Waterside 1 to East River
1:53	Arthur Kill No. 3 at synchronous speed; no feeder available for synchronizing
2:00	Line 71 energized at Dunwoodie into Rainey
	Circuit 38W31 energized at Eastview to Elmsford
2:05	Circuit 96962 energized at Millwood East to Millwood West
	Circuit 96952 energized at Millwood West to Buchanan
2:06	Line 71 tripped at Dunwoodie
2:10	Circuit 38W14 energized at Elmsford
2:15	Circuit 12112L&M energized from Astoria East to Astoria No. 2
2:16	Gowanus No. 1-4 placed on line and tripped
2:20	Circuit 38W32 energized at Eastview to Elmsford
	Circuits 9591, 9592, 40221, and 40222 closed at Kent Avenue, energized from East River
2:24	Circuit 9592 tripped at Kent Avenue
	Circuit 42231 closed at Greenwood, energized from Gowanus
2:25	Circuit 42231 tripped at Greenwood, energized from Gowanus
2:30	59th Street steam generating unit No. 15 placed on line
2:35	59th Street GT 1 tripped auto
2:37	Circuits 38W03 and 38W04 Dunwoodie to Washington Street feeders energized
2:38	Hudson Avenue GT 1 failed to start because of low air and battery voltage
2:43	59th Street No. 15 tripped because of low air and battery voltage
	Elmsford feeder 38W13 energized
2:52	Circuit 18002 (Jamaica to Corona) energized and tripped; lightning arrestor ruptured
	Dunwoodie feeders 99941 and 99942 to Sprain Brook; circuits 38W06 and 38W08 to Granite Hill; circuits 38W09 and 38W10 energized
2:59	Feeders 95331 and 95332 (Buchanan to Indian Point No. 1) energized
3:00	Circuit 99972 closed in at Sprain Brook from Dunwoodie
	74th Street GT 2 failed to start because of lubrication oil pump failure
	Circuit 38W34 energized from Eastview to Elmsford
3:04	Circuits 514 and 516 energized at Waterside 1 to Hell Gate and 74th Street
3:05	Circuit 517 energized at Waterside 1 to Hell Gate and 74th Street
3:07	Circuit 518 energized at Waterside 1 to Hell Gate
3:09	Circuit 519 energized at Waterside 1 to Hell Gate
3:12	Circuit 525 energized at Waterside 1 to Hell Gate
3:17	Circuit 38W32 energized at Eastview to Elmsford
3:20	Circuit 95531 closed at Buchanan, energized from Millwood West
3:21	Bowline Point No. 1 placed on line
3:25	Astoria steam generating unit No. 2 placed on line into North Queens
3:45	Circuit 701 closed and tripped at Hudson Avenue, energized from Jamaica; lightning arrestor ruptured
	Circuit 901 tripped at Jamaica, energized from Valley Stream
	Astoria No. 2 tripped
	Jamaica dead from Valley Stream
	Corona dead from Jamaica
	Astoria East dead from Corona
	North Queens dead from Astoria East
4:09	Arthur Kill steam generating unit No. 3 placed on line into Fresh Kills
4:20	Circuit 901 closed at Jamaica, energized from Valley Stream
4:23	Circuit 18001 energized at Jamaica to Corona
4:25	Gowanus No. 1-4 placed on line and tripped
4:27	Circuits 38W24, 38W01, and 38W02 closed at Elmsford, energized from Eastview
4:30	Ravenswood GTs 1 and 3-4 tripped auto, lost station light and power
4:34	Circuit 34185 energized to Astoria East from Corona
4:40	Circuit 34111 energized at Astoria East to North Queens, energizing circuits 34112, 12111, and 12112 and transformer
4:50	Circuit 34182 closed at Astoria East, energized from Corona, energizing circuit 34129
5:18	Astoria GT 4-2 tripped auto because of loss of field
5:44	Feeder 29212 energized from Fresh Kills to Fox Hills
5:45	Astoria No. 2 placed on line to North Queens
	Circuit 29212 energized at Fresh Kills to Fox Hills
5:57	Circuit 18002 energized at Jamaica to Corona
6:05	Circuits 34186, 34184, and 34181 energized at Corona to Astoria East

Time a.m.	Event
6:19	Line 72 energized at Dunwoodie to Rainey
	Circuits 38M31 and 38M32 energized at Rainey to East 75th Street and West 110th Street
	Circuits 36311 and 36312 energized at Rainey to Vernon
	Circuit 38M35 energized at Rainey to West 65th Street
6:21	Astoria GT 1 tripped auto; deenergized North and South Station light and power bus
6:25	Greenwood breakers 1N and 2N closed, energizing circuit 42232 from Greenwood to Gowanus; immediately deenergized; Fox Hill feeders 29231 and 29232 deenergized
	Arthur Kill No. 3 tripped; low electrohydraulic control pressure
	Fresh Kills shut down
	Fox Hills, Willowbrook, and Wainwright shut down
	Goethals station light and power deenergized
6:39	Circuits 34184, 34186, and 34181 closed at Astoria East, energized from Corona
	Circuit 34123K energized from Astoria East to Astoria No. 3
	Circuit 34124M energized at Astoria East to Astoria 4
	Circuit 34125L&M energized at Astoria East to Astoria No. 5
6:40	Circuit 36252 energized at Rainey to East 75th Street
7:00	Line 62 energized at Rainey to Farragut
7:30	Circuit 34123K energized from Astoria East to Astoria No. 3
	Circuit 99032 energized at Dunwoodie North to Sherman Creek
7:35	74th Street steam generating unit No. 11 placed on line
	Circuit 38M34H energized at East 75th Street to West 110th Street
	74th Street No. 11 on line
7:46	74th Street No. 11 taken off line
7:53	Astoria steam generating unit No. 3 placed on line into Astoria East
7:59	Circuit M52 energized at Sprain Brook to East 13th Street
8:12	Circuit W75L&M energized at Dunwoodie to Sprain Brook
	Circuits M52 and 37373 closed at East 13th Street, energized from Sprain Brook
	Circuits 37372 and 46 energized at East 13th Street to Farragut
8:20	Line W75L&M closed at Sprain Brook, energized from Dunwoodie
	Line 62 tripped at Rainey
8:20	Circuit 38M31 tripped at Rainey
	Circuit 36311 tripped at Rainey
8:21	Circuit 36312 closed at Vernon, energized at Rainey
	Circuit 38M03F energized at Vernon to West 65th Street and West 42d Street
	Circuits 38Q02 and 38Q03 energized at Vernon to Glendale
8:22	Circuit 31232 energized at Vernon to Greenwood
8:40	Circuit 38M01H energized at Vernon to West 42d and West 65th Street
8:42	Circuit 31281L&M energized at Vernon to Queensbridge
8:45	Line 62 energized at Rainey to Farragut
	Circuit 36311 energized at Rainey to Vernon
	Circuit 38M31 energized at Rainey to East 75th Street and West 110th Street
	Circuit 48 energized at Farragut to East 13th Street
	74th Street frequency changer (FC) No. 2 started on 25-Hz system; unable to synchronize because of high frequency
	Circuit 38M04F energized from Vernon to West 65th Street
	Circuits 38M02H and 38M06 energized from Vernon to West 42d Street
	Circuit 31281L&M energized from Vernon to Queensbridge
	Circuits 38Q01 and 38Q02 energized from Vernon to Glendale
	Circuit 31231 energized from Vernon to Greenwood
8:50	Circuit 99151 energized from Dunwoodie to East 179th Street
9:00	74th Street FC 1 started on 60 Hz; unable to synchronize, frequency too high
9:05	Circuit 62 tripped at Rainey to Farragut
	Circuit 48 tripped at Farragut to East 13th Street; transformer No. 8 lightning arrester damaged
	Circuit 32073 energized at Farragut to Hudson Avenue
9:06	Circuit 61 energized at Rainey to Farragut; circuit 36252 to East 75th Street
	Circuit 38B01 energized at Farragut to Brownsville
9:12	Circuit 29231 (Greenwood to Willowbrook) energized
9:13	Circuits 38311, 29321, and 31231 energized from Greenwood to Bensonhurst, Fox Hills, and Vernon, respectively
9:17	Circuit 31232 deenergized from Vernon to Greenwood

Time	Event
a.m.	
9:17	Circuit 31232 closed at Greenwood, energized from Vernon and tripped
9:29	Fresh Kill feeders 38R51, 38R52, and 21212L&M energized
9:33	74th Street FC 1 placed on line
9:35	Circuit 31232 energized at Vernon to Greenwood
9:37	74th Street FC 2 placed on line
9:40	Circuits 29232 and 29212 energized at Greenwood up to Fresh Kills
9:41	Circuit 29212 closed at Fresh Kills, energized from Fox Hills
9:45	Gowanus GTs 2-3, 2-8, and 4-3 and circuit 42231 to Greenwood tripped auto
9:55	Circuit 37044 energized at East 13th Street to East River
	Six ruptured disks blown on low-pressure turbine at Indian Point No. 3
10:10	Circuit 62 energized at Rainey to Farragut
	Gowanus GT barges Nos. 2 and 4 restored
10:14	Circuit 62 closed at Farragut, energized at Rainey
10:15	Arthur Kill No. 2 placed on line to Fresh Kills
	Circuit 42 energized at Farragut to Gowanus
	Circuit 26 energized at Gowanus to Arthur Kill No. 3
10:23	Circuit 46 energized at Farragut to East 13th Street
10:40	Line W81 energized at Pleasant Valley to Millwood West
10:45	Gowanus GT barges Nos. 2 and 4 tripped, reactive power overloading
	Line W81 closed at Millwood West, energized from Pleasant Valley
10:53	Line W93 opened at Buchanan to Eastview
10:55	Kent Avenue FC placed on line
11:00	Tank Nos. 1 and 2 nitro disks ruptured at Pump House for lines 61 and 63
11:02	Line W93 energized at Buchanan to Eastview
11:15	Line 63 energized at Rainey up to Farragut
	Gowanus GT barges Nos. 2 and 4 placed on line, one unit each
11:25	Line 80 energized at Millwood West to Pleasant Valley
	Circuit 99031 energized at Sherman Creek to Dunwoodie North
11:29	Line 80 closed at Pleasant Valley
11:30	Circuit 99031 closed at Dunwoodie North, energized from Sherman Creek
11:37	Astoria No. 2 tripped, electrical fault and pothead damage
11:41	Circuit 23161 energized at Greenwood to Narrows

Time	Event
a.m.	
11:41	Circuit 42231 energized at Greenwood to Gowanus
11:45	Circuit 38B12 energized at Greenwood to Bensonhurst
	Line W99/W64 energized at Millwood West to Eastview and to Sprain Brook line W99/W64
11:52	Circuit 701 energized at Jamaica to Hudson Avenue East
	Circuits 32711 and B43 energized at Hudson Avenue to Farragut
	Line W64 closed at Sprain Brook, energized from Eastview
	Circuit 38M15 energized at Hudson Avenue to Trade Center
11:54	Circuit 38B05 energized at Farragut to Brownsville
p.m.	
12:02	Circuit 702 energized from Jamaica to Hudson Avenue East
12:10	Gowanus No. 2-8 placed on line to Greenwood
12:11	Circuit 37041 energized at East 13th Street to East River
12:12	Gowanus No. 2-3 placed on line
12:16	Gowanus No. 2-7 tripped to Greenwood
12:19	Circuits B43 and 32711 closed at Farragut, energized from Hudson Avenue
12:20	Circuit 63 closed at Farragut, energized from Rainey
	Gowanus No. 4-7 placed on line to Greenwood
12:25	Gowanus No. 4-5 placed on line to Greenwood
12:28	Circuit 32074 energized at Farragut to Hudson Avenue
	Circuit 48 energized at Farragut to East 13th Street; circuits 37376, 37377, and Q35M energized
12:29	Gowanus No. 2-3 tripped
12:31	Circuits 37371 and 38M22 energized at East 13th Street to Waterside 1, East 29th Street, and East 36th Street
12:32	Gowanus No. 4-8 placed on line to Greenwood
12:34	Gowanus No. 4-3 placed on line to Greenwood
12:36	Gowanus No. 4-4 placed on line to Greenwood
12:46	Circuits M51, 37374, and 37375 energized at Sprain Brook up to East 13th Street
	Circuit 45 energized at East 13th Street to Farragut

Time p.m.	Event
12:49	Circuits 37374 and 37375 closed at East 13th Street, energized from Sprain Brook
1:00	Circuit 99151 closed at East 179th Street, energized from Dunwoodie South
	Circuit 15051 energized at East 179th Street to Hell Gate
1:17	Arthur Kill No. 3 placed on line to Goethals, Gowanus, and Farragut
1:37	Circuit 31282L&M closed at Queensbridge, energized from Vernon
	Circuit 28243L&M energized at Queensbridge to Astoria West
1:39	Circuit 38M25 energized at East 13th Street to East 29th Street
1:54	Circuit 38M11 energized at Farragut to Seaport
	Circuit 32071 energized at Farragut to Hudson Avenue
1:55	Circuits B47 and 37378 energized at Farragut to East 13th Street
1:56	Circuit 45 closed at Farragut, energized from East 13th Street
	Circuits 41, 25, and 21 energized at Farragut to Arthur Kill No. 3
	Circuit 32710 energized at Farragut to Hudson Avenue
2:00	Circuits 15031 and 15032 energized at Sherman Creek to East 179th Street
	Circuit 21 opened at Goethals
	Circuit 21 energized at Arthur Kill No. 3 to Goethals
2:02	Circuit 38M24 energized at East 13th Street to East 29th Street, East 36th Street, and Waterside 2
2:04	Circuit 38B03 energized at Farragut to Brownsville
2:06	Circuit 38M23H energized at East 13th Street to Waterside 2
2:08	Circuits 21 and 25 closed at Goethals, energized from Farragut
2:15	Circuit 34123R closed at Astoria No. 3, energized from Astoria East
	Circuit 28243L&M closed at Astoria West, energized from Queensbridge
	Circuit 24129 energized at Astoria into Astoria GT
	Circuits 37376 and 37377 closed at East 13th Street, energized from Farragut
2:30	Circuit 42231 energized at Gowanus to Greenwood
2:31	Circuit 32078 energized at Farragut to Hudson Avenue East
2:36	Circuit 38M13 opened at Farragut
2:55	Circuit 32077 energized at Farragut to Hudson Avenue East
2:58	Circuit 34126 energized at Astoria East to Astoria GT
	Circuit 38M21H energized at East 13th Street to East 29th Street, East 36th Street, and Waterside 1
3:00	Circuit 34186 opened at Astoria East, energized from Corona
	Circuit 32077 closed at Hudson Avenue East, energized from Farragut
	74th Street No. 11 placed on line
3:05	Circuit 38M26H energized at East 13th Street to East 36th Street, Waterside 1, and Waterside 2
	Ravenswood steam generating unit No. 2 placed on line into Vernon
3:15	Circuit 32078 closed at Hudson Avenue East, energized from Farragut
	Circuit X28 energized at Sprain Brook to Tremont
3:30	Circuit 15031 closed at East 179th Street, energized from Sherman Creek
	Circuits 38X01 and 38X04 energized at East 179th Street, to Parkchester and to Tremont
3:33	Circuit 34186 energized at Astoria East to Corona
	Circuit 34127 energized at Astoria East to Astoria GT
3:38	Circuit 34186 closed at Corona, energized from Astoria East
3:45	Circuit 32072 closed at Farragut to Hudson Avenue
3:52	59th Street FC 1 placed on line
3:54	59th Street No. 13 tripped, ruptured blowdown line
4:00	Circuit 15032 closed at East 179th Street, energized from Sherman Creek
	Circuit 38X03 energized at East 179th Street to Parkchester and up to Tremont
	Circuit 31218L&M opened at Vernon
4:02	Circuit 37378 closed at East 13th Street, energized from Farragut
4:10	Circuit 32075 energized at Farragut to Hudson Avenue
4:11	Circuit 99152 energized at Dunwoodie South to East 179th Street
4:23	Circuit 99152 closed at East 179th Street, energized from Dunwoodie South; circuit 15155 energized
4:28	Line Y98 energized at Millwood West to Buchanan South
4:30	Circuits 22391 and 22392 energized at Kent Avenue to John Street
4:34	Line Y98 closed at Buchanan South, energized from Millwood West
4:35	Circuit 38M24H tripped at East 13th Street

Time	*Event*
p.m.	
4:35	Circuit 31281L&M energized at Vernon to Queensbridge
4:36	Ravenswood No. 2 tripped, trouble with ID fan interlock
4:44	Circuits 38X01, 38X03, and 38X04 closed at Tremont, energized from East 179th Street
4:45	Circuit 71 breakers tripped at Rainey
4:50	Circuit 31281L&M closed at Queensbridge, energized from Vernon
	Circuit 28244L&M energized at Queensbridge to Astoria West
	Circuit 28242 energized at Queensbridge to Astoria West
	Circuit 15052 energized at East 179th Street to Hell Gate
	Circuit 38X02 energized at East 179th Street to Tremont
4:54	Waterside FC 2 placed on line
4:55	Circuit 38B01 tripped at Farragut, phase C pothead rupture
5:10	Circuit 38X02 closed at Tremont, energized from East 179th Street
	Circuit 71 breakers closed, energized at Rainey to Dunwoodie
5:15	Circuit 37042 energized at East 13th Street to East River
5:16	Circuit 37043 energized at East 13th Street to East River
5:42	Waterside FC 1 placed on line
5:50	Circuit 28241L&M energized at Queensbridge to Astoria West
5:53	Astoria No. 4 tripped
6:15	Circuit 27244L&M closed at Astoria West, energized at Queensbridge
	Circuits 24051 and 24054 energized at Astoria West to Hell Gate
	Circuits 38X11 and 38X12 energized at Hell Gate to Bruckner
6:20	Circuit 28243L&M closed at Astoria West, energized from Queensbridge
	Circuit 24053 energized at Astoria West to Hell Gate
	Circuit 38X13 energized at Hell Gate to Bruckner

Time	*Event*
p.m.	
6:20	Circuit 24052 energized at Astoria West to Hell Gate
	Hudson Avenue FC placed on line
6:30	74th Street No. 3 placed on line
6:37	Circuit 87873L&M closed at Eastview, energized from Millwood West
6:42	Circuit 32075 opened at Farragut
	Circuit 38B03 opened at Farragut
7:00	Circuit 32075 energized at Farragut to Hudson Avenue
7:07	Indian Point nuclear generating unit No. 3 placed on line to Buchanan South
	Line Y96 closed at Buchanan South, energized at Indian Point No. 3
7:09	Circuit 32072 opened at Farragut
	Circuit 38B05 opened at Farragut
7:16	Circuit 32072 energized at Farragut to Hudson Avenue
7:21	Astoria No. 4 placed on line to Astoria East
7:38	Ravenswood No. 2 placed on line to Vernon
7:55	Circuit 38B05 energized at Farragut to Brownsville
8:01	Circuits 15051 and 15052 closed at Hell Gate, energized from East 179th Street
8:25	Circuit 38B03 energized at Farragut to Brownsville
8:38	Astoria No. 2 placed on line to North Queens
9:02	East River FC placed on line
9:41	East River No. 6 placed on line
9:50	Circuit 23162 opened at Greenwood to Narrows
10:00	Narrows GT barge No. 1 taken off line to Greenwood
10:15	74th Street No. 10 placed on line
10:27	East River No. 6 tripped; low vacuum, both circulators out, burner pulled out
10:31	Waterside No. 14 placed on line
10:40	Circuit 23162 energized at Greenwood to Narrows
11:30	Circuit 99031 closed at Dunwoodie North, energized from Sherman Creek
11:31	Waterside No. 5 placed on line
11:55	East River No. 6 placed on line

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Appendix K

CON EDISON'S COMMUNICATION FACILITIES

The Con Edison communication facilities include radio communication facilities, radio-telephone lines (RTLs), direct telephone lines (leased), and commercial telephone.

Radio communication facilities consist of a six-channel ultrahigh frequency (UHF) system, which operates in a duplex mode; a three-channel very high frequency (VHF) system, which operates in a simplex mode; a substation landline radio system; an Indian Point area radio system; and a two-channel duplex UHF system that is used primarily in gas operations.

The six-channel UHF system operates on six dual frequency pairs. The system consists of six identical UHF mobile relay systems, which include mobile and portable radios, fixed radio control stations, satellite receiver stations, and a repeater station that automatically relays communications between a transmitting point and a receiving point. There are 12 UHF control centers, one of which is a temporary location with two transmitters that could be separated into two separate control centers if necessary.

Five of these control centers are equipped with a six-channel multifrequency transmitter and receiver unit and a single-frequency transmitter and receiver unit. The single-frequency unit is generally used for intradivision operations; the multifrequency units are used as standby or, by proper channel selection, for interdivision communications.

Two of these centers are located in the Bronx (one for electric operations and one for gas), one each in Brooklyn and Queens, and the fifth in the central office at Irving Place. A Manhattan division control center is equipped with a single, six-channel multifrequency unit and two separate single-frequency units; the energy control center is equipped with six separate single-frequency units. The remaining installations consist of multifrequency units. Two of these are located in the Astoria complex, two in the temporary location, and one each in the Westchester Division, Vernon Center, and on Staten Island.

The system operates through a repeater station that receives on the transmitting frequency of the control centers and automatically converts to the receiving frequency of mobile units in the field. Transmissions from the field units are received at the repeater station and are automatically converted to the receiving frequency of the control centers. The main repeater station is equipped with one six-channel multifrequency unit for normal operations and six individual units for backup service. The main repeater station is located in the Empire State Building and is equipped with two emergency power supply installations. The system is also equipped with a backup repeater station located at the central office at Irving Place. The backup repeater station uses six individual transmitting and receiving units for standby purposes and is also equipped with a separate emergency power supply.

In addition to the multifrequency control stations operating on the six-channel UHF system, there are also 30 single-frequency, standby control stations. These control stations are used only in case of emergency and are located at all power generating facilities, at nine central substations in Westchester County and at two city locations. Communications in this sytem are conducted in the duplex mode on the central frequency of the six-channel UHF system and use the same repeater stations.

In addition to the central frequency equipment, the nine central substation locations also have UHF base stations for local communications between the substation control rooms and the yard. These base stations at the substations are tied to the energy control center at West End Avenue via RTLs, which permit the energy control center to use the base station units for direct communication with operators in the station yards.

During the July 13 disturbance these UHF communication systems were totally inoperative after complete shutdown of the Con Edison system and were not available again until approximately 12:05 a.m., July 14. One of the emergency power supplies for the main repeater station was inoperative before the disturbance, and the second failed to start. When attempts were made to use the backup repeater station, the emergency power supply to it also failed to operate. In the period from 9:35 a.m., July 13, to 12:05 a.m., July 14, Con Edison personnel managed to transfer emergency supply for the backup repeater station from its normal emergency gasoline unit to the Irving Place emergency diesel. This transfer has since been made permanent because the diesel was felt to be more reliable than the gasoline unit.

The main repeater station was out of service for approximately 13½ hours, but with the backup station in service, UHF communications were restored to a satisfactory state by 12:05 a.m., July 14.

The three-channel VHF system operates in the simplex mode on three VHF frequencies, two in Westchester (one for gas and one for electric), and one on Staten Island. The Westchester division operation consists of six remotely controlled radio base stations, mobile units, and one radio communications control center. The six remote base stations are remotely controlled from the Westchester control center by RTLs.

The Staten Island system is similar, but it operates on only one channel and uses only three remote satellite base stations. Both the Westchester and Staten Island control centers are also linked by RTLs to the energy control center, allowing the energy control center to use the VHF system of either division. Because these centers also contain part of the six-channel UHF system, the centers can also function as relay stations for the UHF systems.

During the disturbance, both the Westchester and Staten Island VHF operations were disrupted in some areas by the failure of amplification equipment required for RTL operation. The amplification equipment was dependent upon power supplied by the Con Edison system, and after shutdown this power was not available, except where emergency power supplies were in operation or where station light and power supply had been restored. This problem also affected some of the leased, direct telephone lines used throughout the Con Edison system. Since the disturbance, the company has installed uninterruptible power supplies at 30 or more locations on the system to assure the availability of RTL and direct line communications in the future.

The Indian Point area radio system operates in the duplex mode on a dual-frequency pairing, with three control stations, an emergency control station, and an alternate emergency control station. These stations are located throughout the Indian Point area and operate with a suitably located mobile repeater station. Operation in the duplex mode with the mobile repeater station is identical to the operation of the UHF six-channel duplex operation, but the approximate operating range is about 25 miles. All control centers and field units are also equipped with a second transmitting frequency corresponding to the receiving frequency of the field unit and the control station so that communications can be maintained even with failure of the mobile repeating unit.

In addition, one of the normal control centers and the main emergency control center are equipped to communicate on the central frequency of the UHF system, using the main repeater station in the Empire State Building.

Because of the previously mentioned failures at the main and the backup repeater stations for the UHF system and the lack of adequate emergency power for RTL and direct line operation, communications between the energy control center and the Indian Point area during the initial phase of the restoration effort were somewhat restricted.

Overall, the communication capabilities available to Con Edison before the disturbance appeared to be adequate from the standpoint of facilities in place. The possibility of a triple-contingency loss of emergency power supply to the UHF repeater stations was extremely remote, but its occurrence did uncover shortcomings in the emergency operation of RTLs and direct telephone lines. This deficiency has since been corrected. Even with the problems encountered, communications in the early hours, though less than perfect, were maintained via commercial telephone lines held open by operators at both ends and via operative RTLs and direct telephone lines. Some of the problems encountered in the earlier phases of the restoration were partially due to reduced communication capabilities in some areas. In general, however, the communication problems were not considered major by personnel at the energy control center.

Appendix L

ANALYSIS OF CON EDISON'S FUTURE SYSTEM REQUIREMENTS

FORECAST LOAD REQUIREMENTS

During the period 1965 through 1973, Con Edison's system peak load grew from 5,710 to 8,220 MW, an annual rate of growth of 4.7 percent. Con Edison experienced a 2.6-percent reduction in peak load growth in the period 1973 to 1976 after the 1973 oil embargo. Contributing to this has been a depressed economy in the city of New York. About 10 percent of the total office space in Manhattan's central business district is unoccupied, and there are no new large office buildings planned or under construction. Manufacturing employment in the city of New York has been declining for two decades, and personal income there in constant dollars has been on the decline since 1969.

Although some recovery is anticipated, the long-range outlook is that Con Edison's future load growth will not rebound to preembargo rates. Present planning anticipates a future annual load growth rate of 2.7 percent from 1976 to 1986. Con Edison's present 10-year forecast of summer peak demand is—

Year	*Forecast summer peak (MW)*
1977	7,485
1978	7,640
1979	7,860
1980	8,090
1981	8,320
1982	8,550
1983	8,675
1984	8,900
1985	9,125
1986	9,350

ESTIMATED FUTURE POWER SUPPLY REQUIREMENTS

With a moratorium on construction of new generating plants in the city of New York even though sites are available, an increasing amount of generation will need to come from outside of Con Edison's in-city service area. The additional generation will be provided from Con Edison's plants located in upstate New York and in the New York Power Pool (NYPP) area. For Con Edison to be assured of a future reliable power supply, NYPP must have adequate generating capacity, and Con Edison must have adequate transmission-import capability.

NYPP generating capacity is planned with the use of mathematical loss-of-load-probability (LOLP) techniques, which consider the effects of daily, monthly, and seasonal load characteristics; generating unit sizes, forced-outage experience and maintenance requirements; firm purchases and sales of power; and generation value of interconnections. The purpose of these techniques is to optimize the degree of service reliability while attempting to minimize capital expenditures.

Generating capacity is planned to meet a LOLP risk index of 1 day in 10 years. The LOLP risk index is the expected number of days on which system load will exceed available generating capacity without resorting to extraordinary load-relief countermeasures. This is a Northeast Power Coordinating Council (NPCC) criterion to which NYPP companies subscribe.

Generating reserve studies conducted in 1972 determined that NYPP companies would need to maintain generation reserves of not less than 20 percent of annual peak load to maintain an LOLP risk of the 1-day-in-10-years criterion. A subsequent 1975 study has determined that NYPP generation reserves should not be less than 22 percent for the period 1980 to 1990.

Following are NYPP's projected generation reserves for 10 years, as reported to the Federal Power Commission (FPC) on April 1, 1977.[1]

Year	*NYPP projected generation reserves (percent)*
1977	33.1
1978	33.2
1979	31.9
1980	28.3
1981	26.8
1982	24.8
1983	21.4
1984	26.3
1985	23.9
1986	22.7

[1]Northeast Power Coordinating Council, "Data on Coordinated Regional Bulk Power Supply Programs," FPC Order 383-4, Docket R-362, Apr. 1, 1977.

Table L-1.—*Projected Capacity and Projected Energy Mix for the New York Power Pool for 1977, 1985, and 1992*

Capacity type	Capacity (percent) by year			Generation (percent) by year		
	1977	1985	1992	1977	1985	1992
Nuclear	12	16	29	17	20	36
Coal	11	14	14	17	20	19
Oil	60	53	39	44	44	32
Hydro	17	17	18	22	16	13

In addition to having adequate generation reserves, it is becoming increasingly important and even imperative that the fuel mix be as diversified as possible to guard against degradation of service due to fuel-supply problems. At the present time about 60 percent of NYPP's installed generating capacity is fueled by oil. A large portion of this capacity was at one fime fueled by natural gas but because of the national interest in reducing use of natural gas as a powerplant fuel, gas-fired capacity was converted to oil operation. To meet the goals of improved economics and reliability, NYPP's 15-year generation expansion plans emphasize a shift to coal and nuclear power. Table L-1 shows NYPP's projected capacity and projected energy mix for 1977, 1985, and 1992.[2]

CON EDISON TRANSMISSION REQUIREMENTS

Con Edison has a twofold need for transmission capacity. There is a need for substantial transmission capacity to import generation from north of the city to serve normal load requirements, and there is a need for transmission capacity to the west, primarily for emergency power supply.

North Corridor Transmission Requirements

To evaluate Con Edison's north-corridor transmission requirements, the staff made an independent single-area LOLP study of the Con Edison in-city system with a variable interconnection having a 100-percent availability. A series of runs were made, with the interconnection capacity varied in increments to discover the level that results in an LOLP risk equal to 1 day in 10 years for each year from 1977 through 1987. Transmission capacity requirements corresponding to 1 day in 10 years were then increased by 25 percent[3] to provide additional transmission reserve for inertial flows into the NYPP area that can result following a system disturbance. This provides a general indication of Con Edison's transmission capacity requirements needed to the north to supply load requirements in the city of New York at a reasonable risk. Con Edison's current interconnection transfer capability to the north is about 2,500 MW. Present planning calls for this to increase to 3,400 MW by about 1982 and to 5,700 MW by about 1987. Table L-2 summarizes the results of the staff LOLP analysis. Forced outage rates used in the LOLP analysis are shown in table L-3.

West Corridor Transmission Requirements

Under normal conditions, all generators in an a.c. power system operate in synchronism, with the power output of each dependent on the angle of its rotor relative to a reference (synchronously rotating) axis. Any disturbance on the system that changes the power distribution, such as the sudden loss of a transmission line or a generator, is instantaneously reflected at each generator in the form of an accelerating or decelerating torque. The instantaneous response of each generator to the disturbance is related to both the magnitude of the increment of torque and the inertia of the generator rotor. These relationships can be analyzed for a system to show how the various power flows will change instantaneously after a sudden disturbance.

Table L-2.—*Results of Federal Energy Regulatory Staff Loss-of-Load-Probability (LOLP) Analysis*

Year	Isolated LOLP (days/years)	Required firm transfer capacity (MW) to meet standard LOLP[1]	Required transfer capacity (MW), including reserve
1977	25.18	1,850	2,313
1978	40.63	2,090	2,613
1979	55.54	2,300	2,875
1980	72.78	2,490	3,113
1981	107.34	2,810	3,513
1982	132.93	3,035	3,794
1983	151.12	3,150	3,938
1984	191.02	3,360	4,200
1985	218.25	3,580	4,475
1986	230.80	3,800	4,750
1987	240.00	4,230	5,288

[1] Standard LOLP = 1 day in 10 years.

Table L-3.—*Forced-Outage Rates Used in Loss-of-Load-Probability Analysis*

Unit fuel type	Size range (MW)	Forced outage rate (percent)
Fossil	0-389	4.0
	390-599	7.5
	600-799	8.5
	800-1,099	9.5
Gas turbines	All	5.0

[2]1977 Article VIII, Section 149-b of the Public Service Law response by NYPP systems.

[3]This increase is in accordance with recommendation 6, in the Federal Power Commission report *Review of Consolidated Edison Company 1969 Power Supply Problems and Ten-Year Expansion Plans,* Dec. 1969 and recommendations contained in the second paragraph in the FPC report *Review of Consolidated Edison's Company 1972 Summer Power Supply Problems and 20 Years Expansion Plans,* Sept. 1972, p. 13.

For a sudden power deficiency within Con Edison, about 25 percent of the deficiency would be instantaneously made up within the Northeast Power Coordinating Council (NPCC) and about 75 percent of the deficiency would be instantaneously supplied from outside NPCC, most of which would come through the Pennsylvania-New Jersey-Maryland Interconnection (PJM) to the west. Con Edison's transmission capacity requirements to the west are therefore essentially emergency in nature. The amount of emergency capacity needed is determined by the largest possible-but-improbable (PBI) contingency liability. For Con Edison the largest PBI liability in the future is likely to be loss of an entire substation, because it will be increasingly difficult to diversify transmission terminations. Loss of the Buchanan South Substation, which occurred initially on July 13, 1977, is typical of the PBI liability for which emergency transfer capability to the west must be provided. The loss involved 1,310 MW, of which 77 percent, or about 1,000 MW, of transmission capacity to the west should be provided at a minimum. The current maximum transfer capability to the west is about 1,000 MW, with both the Con Edison Farragut to Public Service Electric & Gas Company (PSE&G) Hudson 345-kV cable circuit, and the Con Edison Goethals to PSE&G Linden 230-kV overhead line in service. Without the first circuit, which has been out of service since September 1976 because of a failed phase angle regulator,[4] the normal continuous transfer capability is 533 MW. This was the situation on July 13, 1977.

An NPCC-PJM joint study, completed in 1976, indicated that it would be economically and technically advantageous to increase the transfer capability between PJM and Con Edison to 3,000 MW by about 1990. This would be a gradual phase-in, beginning with the addition of another Hudson to Farragut 345 kV-cable circuit presently scheduled for 1981.

The system map inside the back cover shows existing transmission facilities in service as of July 1977. Table L-4 lists transmission facilities now planned by Con Edison to the year 1988.

VOLTAGE PLANNING REQUIREMENTS

Con Edison's main transmission voltage is 345 kV, overhead in Westchester County and underground in the city of New York. Subtransmission voltage is 138 kV, primarily consisting of underground cables in the city of New York. The company has 153 miles of 345-kV underground cable and 212 miles of 138-kV underground cable now in service. Approximately 87 percent of the company's load is supplied from underground distribution networks.

[4]The Hudson to Farragut 345-kV cable circuit was returned to service on October 4, 1977, without the phase angle regulator. The phase angle regulator is scheduled for service in 1978.

The large amount of underground cables, coupled with the location of major baseload generation north of Con Edison's franchise area, creates unusual reactive power and voltage control problems. Abnormal voltages affect the quality of service and potentially can result in machine instability. The tripping of the Ravenswood No. 3 generating unit after islanding and automatic load shedding on July 13, 1977, resulted from abnormal network reactive power flow and voltage conditions. Voltage control is expected to become an increasingly severe problem for Con Edison.

According to an April 1973 report issued by the Con Edison System Planning Department, a potential peak load, low-voltage problem on the Con Edison system was identified, and a commitment made to study the requirements for system reactive support. Subsequent reduction in peak load estimates have postponed the time when these voltage support devices are needed.

An attempt was made to develop this plan with the use of conventional load-flow techniques. It was determined that this approach was unsatisfactory because of uncertain results and the time required for analysis. Therefore, a broad review of the techniques of voltage analysis was undertaken, which culminated in a plan of action undertaken in May 1976.

This plan consisted of investigations broadly grouped into three areas:

(1) Identification of low-voltage limitations.

(2) Determination of low-voltage operating characteristics of all critical system components, especially generators and load.

(3) Expansion and development of analytical techniques to analyze accurately and effectively low-voltage conditions and to determine optimal solutions.

The following areas of investigation are underway:

(1) It was recognized that the variation of real and reactive load with voltage was a critical factor. Therefore, Con Edison engineers developed a mathematical model of a composite load, consisting of three types of induction motors and lighting load. This model represents load changes as voltage drops to 60 percent of nominal. To verify the model and to allow determination of the proportion of motor load, field tests were conducted at three representative area stations during the summer of 1976. In addition, tests were conducted on various types of fluorescent lights to determine their individual characteristics. The company now has quadratic expressions, based on the model and the tests, for the variation of real and reactive load as a function of voltage.

(2) Con Edison engineers modified the existing Philadelphia Electric Co. load flow computer program to allow representation of load by these quadratic expressions.

(3) On May 25, 1976, a research contract was

Table L-4.—*Proposed Major Con Edison System Transmission Facilities, 1977 to 1992*

Proposed year of service	Terminal substations: From	Terminal substations: To	Voltage (kV)	Number of circuits	Total length (miles)	Conductor: Number per phase	Conductor: Size (kcmil)	Conductor: Type	Type of construction	Proposed month of service
1977	Eastview[1]	Sprain Brook[1]	345	1	10	2	2,493	ACAR	Overhead	May
1978	Jamaica	Lake Success[2]	138	1	9	1	2,500	Cu	Underground	May
	Dunwoodie	Glenwood[2]	345	1	17	1	2,500	Cu	Underground	May
	Mohansic[3]	Millwood West[3]	138	2	15.4	2	2,493	ACAR	Overhead	July
1979	Pleasant Valley[3]	Carmel[3]	138	2	54.5	2	2,493	ACAR	Overhead	February
	Carmel	Mohansic	138	2	11.6	2	2,493	ACAR	Overhead	June
1980	Pleasant Valley[4]	Wood Street[4]	345	2	58.5	2	2,493	ACAR	Overhead	June
	Wood Street[4]	Millwood West[4]	345	2	22.8	2	2,493	ACAR	Overhead	June
1981	Farragut	New York/New Jersey State line	345	1	3.3	1	2,000	Cu	Underground	June
						1	2,500	Cu	Submarine	June
	Ramapo	New York/New Jersey State line	345	1	3.4	2	1,590	ACSR	Overhead	June
1982	Sprain Brook[5]	Dunwoodie[5]	345	1	1.2	2	2,493	ACAR	Overhead	January
	Pleasant Valley[6]	Pleasantville[6]	345	2	88.6	2	2,493	ACAR	Overhead	April
	Buchanan North[7]	Millwood West[7]	345	1	9.5	2	2,493	ACAR	Overhead	May
	Millwood West[7]	Eastview[7]	345	1	8.3	2	2,493	ACAR	Overhead	May
	Pleasant Valley[8,9]	Millwood West[8,9]	345	2	81.2	2	2,493	ACAR	Overhead	June
	Millwood West[10]	Dunwoodie[10]	345	1	19.4	2	2,493	ACAR	Overhead	June
1984	Farragut	Whiteside[2]	345	1	4.8	1	2,500	Cu	Underground	June
1986	Pleasant Valley[11]	Kent[11]	345	2	34.8	2	2,493	ACAR	Overhead	November
	Kent[8,11]	Pleasantville[8,11]	345	2	53.8	2	2,493	ACAR	Overhead	November
	Cornwall	Cornwall East	345	2	4.2	2	2,500	Cu	Submarine	November
						2	2,500	Cu	Underground	November
	Cornwall East	Kent	345	2	18.4	2	1,590	ACSR	Overhead	November
1987	Dunwoodie	Tremont	345	1	7.3	1	2,000	Cu	Underground	June
1988	Dunwoodie	Steinway	345	1	14.1	1	2,500	Cu	Underground	June

Note: ACAR = aluminum conductor, alloy reinforced; ACSR = aluminum conductor, steel reinforced, Cu = copper.

[1] Project relates to rebuilding Millwood West to Sprain Brook 1961 line.

[2] Long Island Lighting Co. substation.

[3] Project relates to rebuilding Pleasant Valley to Millwood 1932 lines.

[4] Project relates to rebuilding Pleasant Valley to Millwood 1932 lines and establishing New York State Electric & Gas Corp. Wood Street taps on rebuilt 1932 lines.

[5] Project relates to rebuilding 345-kV Sprain Brook to Dunwoodie line.

[6] Project relates to establishing Millwood West easterly bypass.

[7] Project relates to discontinuation of Millwood West westerly bypass.

[8] Via Wood Street.

[9] Project relates to energizing 2d rebuilt 1961 line and transferring 1 Wood Street tap to rebuilt Pleasant Valley to Millwood 1961 line.

[10] Project relates to energizing 2d rebuilt 1961 line and establishing a 1961 line bypass of Sprain Brook.

[11] Project relates to establishing Kent switching station.

awarded to the University of Texas, Arlington, to develop a computer program that would allow for the optimal determination of reactive support devices.

(4) The Con Edison Engineering Department is engaged in a project to determine customer low-voltage limitations and overexcitation characteristics of generators. They are also seeking to identify all voltage-dependent relays that would reduce generator output or trip the generator for low-voltage conditions. Detailed voltage analysis is planned to commence during 1978.

Appendix M

EFFECTS ON NEIGHBORING SYSTEMS

During the FERC staff investigation, an effort was made to examine the manner in which interconnected neighboring systems were involved in events leading to the July 13, 1977, failure and the effects of the failure on these systems. The five neighboring systems most directly affected were—

(1) Central Hudson Gas & Electric Corp. (CHG&E)
(2) New York State Electric & Gas Corp. (NYSE&G)
(3) Long Island Lighting Co. (LILCO)
(4) Public Service Electric & Gas Co. (PSE&G)
(5) New England Power Exchange (NEPEX)

Figure M-1 provides a schematic diagram of major interconnections.

CENTRAL HUDSON GAS & ELECTRIC CORP.

The CHG&E system is located to the north of Con Edison and along the 345-kV north-south transmission corridor serving Con Edison. CHG&E is tied into the 345-kV system at the Rock Tavern Substation, west of

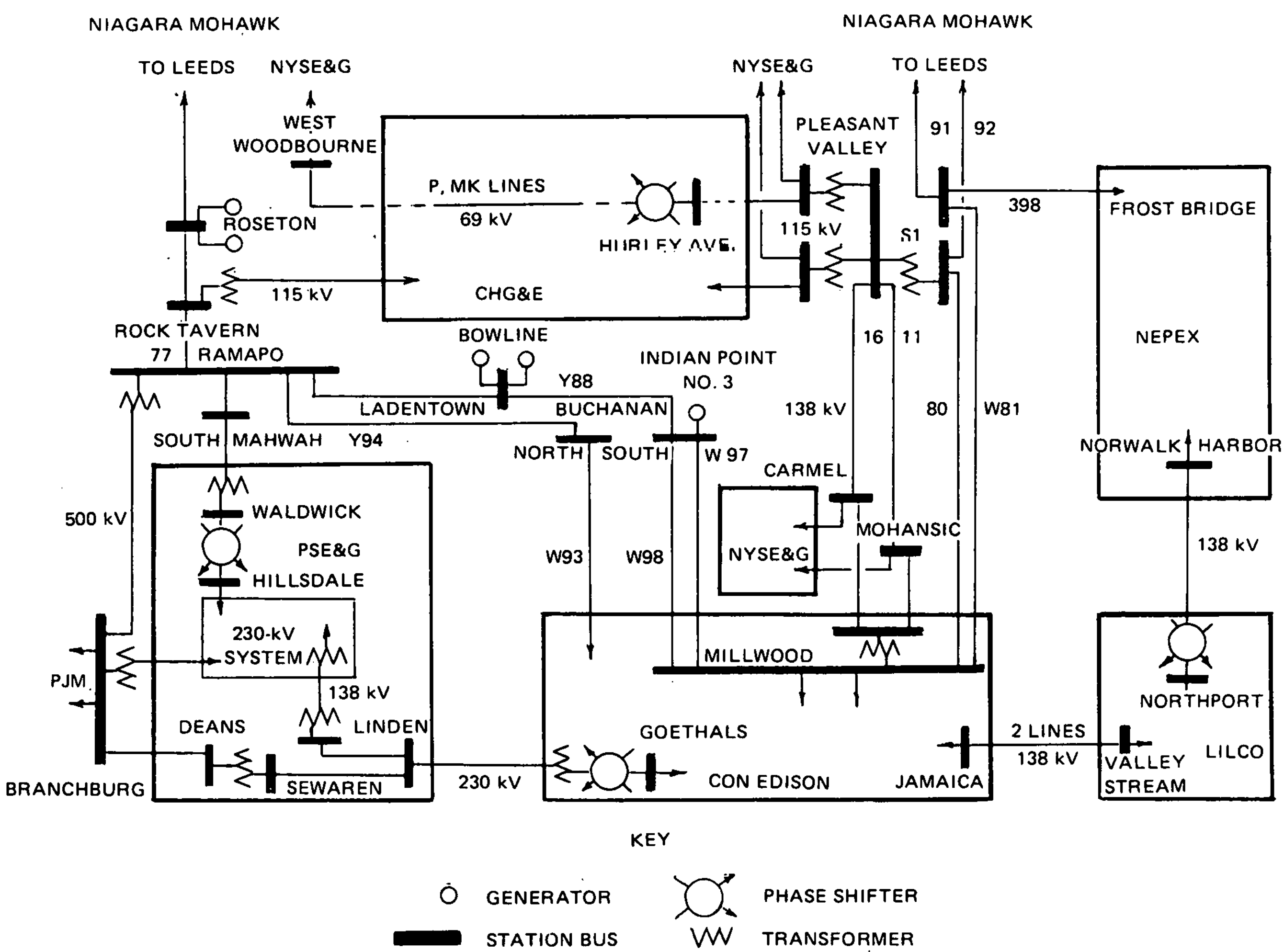

Figure M-1.—Schematic diagram of interconnections and disturbance-affected circuits, Con Edison and neighboring systems.

the Hudson River, and at Pleasant Valley Substation, east of the Hudson River. Its owned generation, as well as the jointly-owned Roseton Plant, which CHG&E operates, is located west of the river.

The first indication of a major system disturbance that CHG&E received was some low-voltage alarms as a result of the first lightning-induced incident, at 8:37:17 p.m. At 8:55:53 p.m., the time of the second incident, additional low-voltage alarms appeared. From this time until about 9:10:00 p.m., a 69-kV line (P line), which is part of a circuit connecting CHG&E to NYSE&G to the west and a 115-kV line (X line) from Reynolds Hill to Pleasant Valley Substation reached and slightly exceeded their "normal" summer ratings.

At 9:13:00 p.m., CHG&E was asked by the New York Power Pool (NYPP) dispatcher to reduce the generation from the Roseton Plant by 200 MW to relieve the loading on the Pleasant Valley to Millwood (80) 345-kV circuit. Roseton was generating 1,135 MW at 9:12:59 p.m. At 9:18:59 p.m., just before the fault on the 92 line, which was the only 345-kV supplying the Pleasant Valley Substation and the 80 line, the Roseton generation had been reduced to 1,061 MW, a reduction of 74 MW. This change could not have been much help in reducing the loading on the 80 line, because the W93 345-kV line (which might have picked up load) was not in service.

At 9:19:11 p.m., when the 92 line opened, a number of lines in CHG&E's system showed heavy west-to-east power flows. This was because CHG&E is tied to the Con Edison 138-kV system that was the only supply to the 345-kV Pleasant Valley bus and 80 line through the S1 transformer bank.

CHG&E's operator received an internal 69-kV P and MK line transfer-trip overload alarm at this time. The system operator was unable to reduce the loading on the P line by adjustment of CHG&E's Hurley Avenue Substation phase shifter. A circuit breaker at the West Woodbourne Substation tripped at 9:29:00 p.m., effectively stopping west-to-east flows on the 69-kV network and eliminating overloads on the P and MK lines. There was no loss of customers as a result of this operation. It was not until 9:34:00 p.m. that this circuit breaker was successfully closed by the NYSE&G system operator.

At 9:19:53 p.m., just shortly after the 92 line tripped, the S1 transformer between the 345-kV bus and the 138-kV system at Pleasant Valley Substation tripped when the load on the transformer exceeded its short-time emergency (STE) rating and overcurrent protective relay settings. Following this trip, line loadings on several circuits connecting the internal generation west of the Hudson River to CHG&E's major load area east of the river returned to less than "normal" summer limits.

If the S1 transformer at the Pleasant Valley Substation had not tripped, the CHG&E internal transmission connecting the generation to the west with the load to the east may very well have been overloaded and possibly tripped. This would have isolated load from generation with resultant partial or complete collapse of CHG&E's system.

At 9:25:00 p.m., NYPP requested that CHG&E further reduce output of the Roseton as well as the Danskammer generating plants. By about 9:43:00 p.m., the Roseton and Danskammer outputs had been reduced to 500 and 285 MW, respectively.

When Con Edison lost its Linden to Goethals tie at 9:29:41 p.m., the only remaining ties were the two 138-kV lines to Pleasant Valley through two 115-kV/138-kV transformers from the CHG&E 115-kV system and other upstate systems. The severe power swing opened circuit breakers R61 on the Pleasant Valley to Mohansic (11) 138-kV line and R62 on the Pleasant Valley to Carmel (16) 138-kV line.

The only other incidents affecting CHG&E were voltage and power swings associated with the tripping of Orange and Rockland Utilities, Inc., 600-MW Bowline No. 1 unit at 10:35:00 p.m. and Con Edison's unsuccessful attempted pickup of the 80 and W81 lines at 10:38:00 p.m. Following these incidents, the CHG&E system returned to normal.

NEW YORK STATE ELECTRIC AND GAS CORPORATION

Following the loss of the last remaining ties (11 and 16) to the Con Edison system, a portion of NYSE&G's Brewster District load was left interconnected with Con Edison's system. The Brewster District is in southeastern New York and geographically isolated from the main NYSE&G system.

At about 9:36:00 p.m., when the Con Edison system completely shut down, about 70 MW of NYSE&G load were lost, affecting 35,000 customers.

At 10:32:00 p.m. on July 13, the NYSE&G system operator reported to NYPP their ties with Con Edison at Carmel and Mohansic Substations were open and requested that CHG&E energize the 11 and 16 138-kV lines from Pleasant Valley. At 10:44:00 p.m. the 16 line was energized, restoring service to Carmel, and at 10:48:00 p.m. the restoration of NYSE&G customers began. At 11:08:00 p.m. the 11 138-kV line was energized, returning service to Mohansic. At this time NYSE&G completed its restoration of all interrupted customers in the Brewster District.

LONG ISLAND LIGHTING COMPANY

LILCO is interconnected with Con Edison through a double-circuit 138-kV Jamaica to Valley Stream underground transmission tie. LILCO's only other external interconnection is with NEPEX through a double-circuit 138-kV submarine cable from Northport, Long Island, N.Y., to Norwalk Harbor, Conn. There are seven individual cables under Long Island Sound. Three cables are used for each of the two circuits, and one is used as a spare. However, on July 13, two cables had been previously damaged; so only one circuit was available.

Before the first incident, the Jamaica to Valley Stream tie was carrying 267 MW from Con Edison to LILCO. Also, LILCO was importing about 140 MW over the Norwalk Harbor to Northport tie. At about 8:43:00 p.m., NYPP called LILCO to request that generation be picked up because of the loss of Indian Point No. 3 nuclear unit. Over the next 10 minutes, LILCO raised its generation by about 60 MW, reducing imports from Con Edison. The import on the Connecticut tie remained nearly constant because of automatic phase angle control (phase shifter) of the power flow on the line.

Just after the second incident, at 8:55:53 p.m., the Jamaica to Valley Stream tie flow decreased to a very low value. However, the Connecticut tie exceeded its STE rating of 250 MW by about 150 MW. The LILCO system operator manually operated the phase shifter to minimize the power flow to LILCO from NEPEX. The tie flow was reduced to near its STE rating in about 7 minutes, at 9:03:00 p.m. The phase shifter was set at its maximum capability for reducing the tie power flow into LILCO.

At 9:04:36 p.m., NYPP ordered LILCO "... get all the generation out that you can get down there." By 9:10:00 p.m., NYPP requested LILCO to go to 5 percent voltage reduction, for an estimated 75-MW load reduction. Between 9:10:00 p.m. and 9:19:00 p.m., LILCO started seven gas turbines, amounting to 188 MW, and brought on line Northport No. 3, a steam unit rated at 386 MW.

LILCO's primary concern was to bring the Northport to Norwalk Harbor tie down to the "normal" rating of 150 MW and at the same time provide Con Edison with some load relief. LILCO managed in about 23 minutes after the second incident to raise their generation by about 267 MW, including 160 MW in gas turbines and 88 MW from the Northport No. 3 unit. LILCO's interchange with Con Edison changed from importing 192 MW before the second incident to exporting 46 MW just before the third incident, at 9:19:53 p.m. Also, LILCO's load reduction through a 5-percent voltage reduction was completed. The net effect of LILCO's actions in this period was the total change in power flow of about 238 MW to benefit Con Edison as well as to reduce the temporary excursion of the Norwalk Harbor to Northport tie above "normal" and STE ratings.

The opening of the 92 line (third incident) at 9:19:11 p.m. and the tripping of the S1 transformer (fourth incident) at 9:19:53 p.m. caused the flow on the Norwalk Harbor to Northport tie to increase to 340 MW, which is well above its STE rating. At the same time, the Jamaica to Valley Stream tie flow increased to 311 MW toward Con Edison. The LILCO system operator, after consulting with the NYPP dispatcher, decided to shed load to reduce the Connecticut tie flow. LILCO shed 377 MW in about a 1-minute interval, affecting approximately 157,000 customers. However, the Con Edison tie at 9:22:05 p.m. was up to 468 MW and still increasing during the load-shedding operation. The tie exceeded its "normal" rating of 300 MW and was approaching its STE rating of 548 MW. At the same time, the Connecticut tie flow reduced to about 185 MW. The LILCO system operator's instrumentation of the Jamaica to Valley Stream tie flows went off scale at 500 MW. The LILCO system operator had no way of knowing how much the tie exceeded 500 MW.[1] With the Connecticut tie still above its "normal" rating, LILCO's system operator, with the approval of the NYPP dispatcher, opened the Jamaica to Valley Stream tie to protect his system and thus initiated the fifth incident at 9:22:11 p.m. As a result of the July 13 incident, LILCO has increased the scale of the Jamaica to Valley Stream tie flow instrumentation from 500 MW to 600 MW, which is above the STE rating.

Immediately following the opening of the Jamaica to Valley Stream tie, the Norwalk Harbor to Northport tie power flow swung from importing about 185 MW to exporting about 335 MW because of excess generation on LILCO's system. The LILCO system operator began to reduce generation and to restore the previously shed load. This operation was completed by 9:25:00 p.m. with the Norwalk Harbor to Northport tie then exporting about 83 MW to Connecticut. The voltage reduction performed earlier was terminated by 9:42:00 p.m.

PUBLIC SERVICE ELECTRIC AND GAS CO.

The PSE&G service area is in northern and central New Jersey. Its electric facilities are interconnected with Con Edison through (1) a 230-kV overhead transmission line from Linden Substation, in New Jersey, to the Goethals Substation, on Staten Island, (2) a 345-kV submarine cable from Hudson Substation, in New Jersey, to the Farragut Substation, in Brooklyn, and (3) a 345-kV overhead and underground line from Waldwick Substation, in New Jersey, to Ramapo Substation, in Rockland County, New York. The Hudson to Farragut tie was out of service on July 13.

PSE&G is a member of the Pennsylvania-New Jersey-Maryland Interconnection (PJM). Con Edison is further interconnected with the PJM 500-kV system by way of a single-circuit 500-kV overhead line from Branchburg, New Jersey, to Ramapo Substation.

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[1]A swing of about 520 MW on the Connecticut tie at the time the Con Edison tie was opened implies a 520 MW flow on the Jamaica to Valley Stream tie just before its being opened.

The PSE&G system operator first became concerned about the Linden to Goethals tie affecting their own system security when, after the second incident on Con Edison's system at 8:55:53 p.m., the tie-flow instrumentation at Linden went offscale (800 MW). However, about 7 minutes later the tie flow was brought back to about 540 MW by the Con Edison system operator's control of the phase angle regulating transformer at the Goethals Substation. PSE&G rates the Linden to Goethals tie at 510 MW as "normal" and 720 MW as "4-hour emergency."

At 8:58:38 p.m., the PJM interconnection dispatcher was told by the NYPP senior pool dispatcher that Con Edison has "a major emergency over there." He informed PJM of his instruction to Con Edison, wherein he said, "I told him he'd better shed some load down there." The PJM dispatcher said, "Yeah. PS [PSE&G] is going to open that Linden/Goethals if they don't do something about it." At 9:01:41 p.m., PJM was further informed by the NYPP of the problem and that Con Edison was to shed 400 MW of load but had not as yet. At 9:03:01 p.m., the PJM dispatcher saw that the Linden to Goethals tie flow was being reduced. PSE&G's system operator was in communication primarily with the PJM dispatcher.

The second incident also caused the PSE&G's system operator to dispatch personnel to the Waldwick Substation for the purpose of controlling the phase shifter and to the Linden Substation for the purpose of opening the Linden to Goethals tie should the need arise. The Newark, New Jersey, control center was not able to control the phase shifter or the Con Edison tie remotely because of a communication channel failure.

NYPP was importing about 211 MW from PJM on the Branchburg to Ramapo tie before 8:55:53 p.m. The flow reversed as a result of the second incident to 167 MW from north to south, for a change of 378 MW, or about 60 percent of the increase in the Linden to Goethals flow. The remaining 40 percent of the Linden to Goethals increased flow was through three PSE&G's 138-kV cables tied to their 230-kV system to the north. Therefore, as the north-south 345-kV ties from upstate New York to Con Edison tripped, a part of the resultant power swings came through the PSE&G system to the west. However, after corrections were made as a result of Con Edison and PSE&G actions, conditions appeared stabilized and normal on the PSE&G system until 9:19:53 p.m.

At the time of the third and fourth incidents, the loss of the 92 345-kV line and the S1 transformer, the Linden to Goethals tie flows again moved up and off scale. The tie flow at this time was 1,090 MW. The Linden to Goethals tie exceeded 1,200 MW at 9:22:11 p.m., when LILCO opened its tie with Con Edison. Also, the Linden Substation operator's instrumentation was now off scale at 1,000 MW. At this time PSE&G's Waldwick to Hillsdale tie was close to the 660-MV·A 15-minute rating for the phase angle regulator at Waldwick. Also the Linden to Sewaren tie was at 897 MW and above its 746-MW emergency rating.

The PJM dispatcher again was informed of the situation by NYPP and was informed that Con Edison was told to shed 600 MW of load. Also, in the PSE&G dispatch office, the system operator was in communication with personnel at Linden Substation for the purpose of opening the tie, upon orders from the system operator. However, before protective action was taken by PSE&G, the tie opened from a fault on the Goethals phase regulator at 9:29:41 p.m., and PSE&G's internal line loadings returned to normal.

If the Linden to Goethals tie had not opened, and the Sewaren-Linden 230-kV line, which was over its emergency rating, had opened, a large portion of the flow of over 1,200 MW would have surged through three 138-kV cables, probably with serious consequences including loss of load on PSE&G's system.

As a result of the July 13 incident, PSE&G has taken the following actions:

(1) Increased the scale of the Linden to Goethals tie flow instrumentation from 800 to 1,500 MW in the Newark dispatch center

(2) Installed a direct telephone "hot-line" from Newark dispatch center to the Con Edison energy control center

(3) Installed separate channels for controlling the Waldwick phase shifter and the Linden to Goethals tie from the Newark dispatch center to reduce the chance that both might be uncontrollable because of a single outage of a communication channel

THE NEW ENGLAND POWER EXCHANGE

Before the first incident, NEPEX was selling emergency power to NYPP, which in turn was selling emergency power to PJM. After the first incident, the NYPP power dispatcher was in contact with NEPEX and PJM, informing them of his intention to cut the emergency sale of 250 MW from NEPEX to PJM via NYPP at 8:40:00 p.m. The purpose was to relieve the loading on the W81, 345-kV line.

The overloading on the Norwalk Harbor-Northport tie caused some momentary overloads on Connecticut Light and Power Co.'s 115-kV system. There were no interruptions to customers or equipment damage as a result of these overloads. The power excursions of the Norwalk Harbor to Northport tie above its STE ratings were by far the most serious concern of NEPEX. If LILCO had not taken the actions it did, NEPEX would likely have opened that tie to prevent damage.

Appendix N

ACTIONS TAKEN BY CON EDISON RELATED TO RECOMMENDATIONS MADE BY THE FEDERAL POWER COMMISSION AND BY THE NEW YORK PUBLIC SERVICE COMMISSION AFTER THE JULY 13 AND 14, 1977, POWER FAILURE

The abbreviations for the references cited in the tables in this appendix are—

Abbreviation	*Reference*
FPC CED 77	Federal Power Commission, *Staff Report on July 13–14, 1977, Electric System Disturbance on the Consolidated Edison Company of New York, Inc., System*, Aug. 4, 1977
NYPSC CED 77	New York Public Service Commission, *The Events Leading to the Consolidated Edison Company Blackout of July 13, 1977, Second Report*, Sept. 15, 1977

Table N-1.—*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: Control Center*

Recommended item	Reference	Con Edison action	FERC staff comment
Improvement of energy control center	NYPSC CED 77, rec. 4, p. v-2	Floating-point hardware will be added to computer facility to reduce computation time of contingency analysis program. Load-shedding and voltage-reduction controls will be simplified by Jan. 30, 1978. Procurement specification for dynamic mimic board and advanced computer control system was submitted in June 1977. Additional circuit-breaker status indicators have been added on mimic panel for Buchanan, Dunwoodie, Eastview, and Tremont Substations. For remaining 345-kV substations, status indicators will be installed by May 1978. Boeing Co. was requested to review the specifications for system-operations computer-control system (SOCCS) in light of events of July 13 and 14, 1977. Boeing Co. completed review Oct. 1977. It concurred with basic specifications for SOCCS and recommended some additional hardware to improve communications. SOCCS is scheduled for preliminary operation by Dec. 1979 and completion by Dec. 1981.	Progress is satisfactory.
Additional temporary staffing at energy control center	NYPSC CED 77, rec. 5, p. v-2	Position of senior district operator to coordinate all switching for the system operator was added Aug. 22, 1977. Senior district operator will be replaced April 1978 by senior system operator, around the clock, who will work in a pilot-copilot relationship with system operator. Storm watch was instituted on July 10, 1977, and beginning Aug. 10, 1977, additional operating personnel were trained to man storm watch at control center.	Company has complied fully.
Installation of events recorder and data logger	NYPSC CED 77, rec. 26, p. v-8	Con Edison had an events recorder before July 1977. Since July 1977 it has been improved and expanded. Events recorders are scheduled to be installed at major substations by Dec. 1978.	Company has complied fully.

See footnotes at end of table.

Table N-1.—*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: Control Center*—Concluded

Recommended item	Reference	Con Edison action	FERC staff comment
Use of transmission-line-loading instruments having scales exceeding emergency rating of line	NYPSC CED 77, rec. 25, p. v-8	12 of the 24 meters and chart recorders requiring modifications have been completed. All modifications are to be completed by March 1978.	Progress is satisfactory.
Dissemination of emergency information to the public and civil authorities	NYPSC CED 77, rec. 16, p. v-6	Con Edison has an established program for requesting customer assistance in reducing load where need is known in advance and for notification of civil authorities during emergencies. Emergency notification procedures are being reviewed. Audit is being made by Boeing Co. of notification procedures and is scheduled for completion by March 1978. Senior district operator is now responsible for assuring that proper notification is given.	The new procedures should be tested periodically, and test results reported to the appropriate authorities.
Revision of manual load-shedding scheme	NYPSC CED 77, rec. 13, p. v-4	Simplification of manual load-shedding controls is to be completed in Jan. 1978. An automated load-shedding scheme to supplement manual program is being considered. Load would be shed automatically if loadings on selected ties exceed emergency rating.[1]	Con Edison should report its conclusions regarding automated load shedding.
Resolution of inconsistency between NYPP and Con Edison operators of action needed when emergency line loadings are exceeded	NYPSC CED 77, rec. 15, p. v-5	–	Both NYPP and Con Edison operators recognized that short-time emergency rating was being exceeded on July 13, 1977. There was no inconsistency regarding the ratings but rather each operator differed on action to be taken to reduce line loading. NYPP task force is reviewing this.

Note: NYPP = New York Power Pool; rec. = recommendation.

[1] The Con Edison E-58-1 instruction manual, covering load shedding in emergencies, indicates that load should be shed manually whenever the loading on a transmission line exceeds its short-time emergency rating.

Table N-2.–*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: Selection, Training, and Supervision of Personnel*

Recommended item	Reference	Con Edison action	FERC staff comment
Reassessment of Con Edison internal emergency procedures and training of control center personnel to cope with emergencies	FPC CED 77, rec. 6, p. 5	Out of 50 emergency operating procedures about half had been updated before July 13, 1977. Remainder are under review.	Increased effort is needed in this area.
Formal training of control center personnel	NYPSC CED 77, recs. 7 and 10 p. v-3	Formal training consists of short course at Iowa State University. Informal training consists of completion of distribution splicing, network protector and switching courses, observation of substation switching; seminars on operating problems and control strategies, and annual visits to NYPP control center. Ladder system of progress requires 10 to 12 years of on-job training to reach top level of system operator.	More aggressive effort is needed. Con Edison should seek assistance from qualified training consultants.
Installation of control system simulator with periodic checkout of personnel	NYPSC CED 77, rec. 8, p. v-3	Temporary training simulator is scheduled for installation by June 1978. Full simulator is to be developed with SOCCS system. (See table N-1.)	Progress is satisfactory.
Periodic physical and psychological examination of system operators	NYPSC CED 77, rec. 9, p. v-3	Before July 13, 1977, there was voluntary physical fitness program. Mandatory program including both annual physical and psychological testing has been implemented. In addition, Con Edison has arranged for psychological evaluation of candidates for system operator and the new senior system operator positions.	Company has complied fully.
Training of system operators in proper use of manual load shedding	NYPSC CED 77, rec. 12, p. v-3	Con Edison has well-developed standard operating procedure (Manual E-58-1) pertaining to manual load shedding.	Additional emphasis should be given to timing and physical procedure of manual load shedding to assure that all system operating personnel are fully competent in this area.[1]
NYPP certification of control personnel	NYPSC CED 77, rec. 11, p. v-4		It is being considered by a task force of the NYPP.
Establishment of precise terminology and information dissemination between operators of different systems	NYPSC CED 77, rec. 6, p. v-3		NYPP task force has been established to evaluate this. Report is due in early 1978.

Note: NYPP = New York Power Pool; rec. = recommendation; recs. = recommendations.

[1] System operator stated in deposition before city of New York panel investigating blackout that he had never gone through actual voltage-reduction or load-shedding procedure since installation of equipment in control center.

Table N-3.—*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: Operating Reserves*

Recommended item	Reference	Con Edison action	FERC staff comment
Adequate amount of operating reserves	FPC CED 77, rec. 8, p. 5	Since July 13, 1977, Con Edison has increased ratio of in-city generation to total system load during storm watches.	Reserve situation needs to be reviewed in light of heavy imports of economy power.[1]
Examine role of gas turbines in emergencies	NYPSC CED 77, rec. 21, p. v-7	Original role of gas turbines was for peak-load purposes and not for emergency reserve. Combination of manning and remote-start control is being considered to increase flexibility of gas turbines for both peak-load and emergency purposes.	NYPP task force is reviewing role of gas turbines in operating reserve allocation and in meeting system emergencies.

Note: NYPP = New York Power Pool; rec. = recommendation.

[1] These actions may reduce economy of power supply under statewide economic dispatch.

Table N-4.—*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: Design and Operation of Protective Systems*

Recommended item	Reference	Con Edison action	FERC staff comment
Frequent review of relay protection	FPC CED 77, rec. 9, p. 6	Since July 13, 1977, Con Edison has modified test procedures to test protective schemes as systems in addition to testing individual components. Since 1970, testing is performed at least annually, and status is monitored each month by computer.	Company has complied fully.
Circuit breaker reclosing practice	NYPSC CED 77, rec. 24, p. v-8	Con Edison has modified its reclosing practice since 1965 in accordance with generator manufacturer recommendations. Since July 13, 1977, Con Edison has increased allowable reclosing angle.	The practice of reclosing line circuit breakers in vicinity of generating stations is controversial, industry-wide. Continued review is needed.
Flexibility of switching arrangements to maximize reliability	NYPSC CED 77, rec. 17, p. v-6	Since July 13, 1977, conversion of some 138-kV is in progress and installation of underground d.c. circuits is under consideration. Circuit-breaker arrangements at Buchanan and Pleasant Valley Substations are being reviewed, and changes are expected.	Diversity of line routing and switching arrangements is difficult in Con Edison System because of geographical limitations.
Analysis of lightning performance of overhead lines	NYPSC CED 77, rec. 21, p. v-7	Earlier Con Edison study concluded that probability of two double-circuit lines tripping out from lightning during same storm was once every 1,300 years, a figure based on design footing resistance of 10 Ω. Con Edison now plans to measure footing resistance at every tower, and where resistance is greater than 10 Ω, to take steps to reduce resistance to lowest practical value. All towers are expected to be corrected by end of 1979.	Evaluation has been completed and recommendations on line modifications are pending.
Substation shielding against lightning	NYPSC CED 77, rec. 22, p. v-7	Con Edison's transmission-line towers surround their substations and are themselves so shielded that substations are inherently protected from lightning.	Existing lightning protection is considered adequate, but additional shielding is being considered.

Note: rec. = recommendation.

Table N-5.—*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: Emergency Planning and Operation*

Recommended item	Reference	Con Edison action	FERC staff comment
Auxiliary power to maintain underground cable oil pressure	FPC CED 77, rec. 7, p. 5	Con Edison uses selective switching of lines to make generation station power available to pressurize cable during restoration. Temporary emergency generators have been installed at major substations and were ready for service Aug. 26, 1977. They will be replaced by permanent facilities by June 1979.	Switching procedures to provide power to underground cables need improvements.
Consideration of modification of automatic load shedding as a result of July 13, 1977, power failure	FPC CED 77, rec. 5, p. 5; NYPSC CED 77, rec. 13, p. v-5	Con Edison is considering disconnecting capacitor banks by automatic underfrequency relays to overcome irregular voltage patterns associated with load shedding on underground feeders. Simplified manual load shedding controls were scheduled for completion Jan. 1978.	Con Edison should report its conclusions regarding automatic disconnection of capacitor banks.
Automation of gas turbines for remote startup	FPC CED 77, rec. 4, p. 4; NYPSC CED 77, rec. 19, p. v-7	Gas turbines are being manned full time until remote startup feature can be installed. Tests are being concluded on Narrows gas turbines, which have been equipped for remote start.	Progress is satisfactory.

Note: rec. = recommendation.

Table N-6.—*Actions Taken by Con Edison Related to Recommendations, Since July 13, 1977: System Planning*

Recommended item	Reference	Con Edison action	FERC staff comment
Restoration of Hudson/Farragut 345-kV tie with PJM	FPC CED 77, rec. 1, p. 4	Forced cooling of in-city underground cables was implemented beginning in Sept. 1977, increasing the transmission-cable capability and permitting the Hudson/Farragut tie to be reestablished without the phase angle regulator. Effective date was Oct. 13, 1977.	Action is temporarily complete. New phase angle regulator was to be installed Apr. 1978 to complete the restoration.
Improvement in area security by location of additional generation close to the Con Edison load center	FPC CED 77, rec. 10, p. 6	A memorandum of understanding between the city and Con Edison was signed Aug. 22, 1970, in which Con Edison agreed to discontinue construction of new steam electric generating capacity in the city.	Con Edison is legally and environmentally hampered from providing new in-city generation. PASNY recently proposed new generation on Staten Island.
Reevaluation of Con Edison north-south corridor transfer capability and limitations	NYPSC CED 77, rec. 2, p. v-1	On-line computerized contingency analysis is now used to modify allowable line loadings consistent with system conditions and configuration.	This area is being studied both by the company and by NYPP.
Advance construction of new Hudson/Farragut 345-kV tie to PJM to earliest possible date	FPC CED 77, rec. 2, p. 4	The second Hudson/Farragut tie is being negotiated with Public Service Electric & Gas Co. of PJM, and discussions are proceeding satisfactorily.	Action is in progress.
Construct new Linden/Geothals 230-kV tie to PJM	FPC CED 77, rec. 2, p. 4	Recommendation was studied and rejected.	Action would require additional reinforcement of PJM internal 230-kV system to implement.
Advance construction of Farragut/Whiteside 345-kV tie with Long Island Lighting Co.	FPC CED 77, rec. 3, p. 4	The purpose of this tie is to provide backup to Long Island Lighting Co.'s Jamesport nuclear plant scheduled for service in 1984.	Need for this line is contingent upon completion of the Jamesport plant.

Note: PASNY = Power Authority of the State of New York; PJM = Pennsylvania-New Jersey-Maryland Interconnection; rec. = recommendation.

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Appendix O

ACTIONS TAKEN BY CON EDISON RELATED TO RECOMMENDATIONS MADE BY VARIOUS AGENCIES FROM NOVEMBER 1965 TO JULY 13, 1977

The abbreviations for the references cited in the tables in this appendix are—

Abbreviation	*Reference*
FPC CER 69	Federal Power Commission, *A Review of Consolidated Edison Company 1969 Power Supply Problems and Ten-Year Expansion Plans,* Dec. 1969
FPC CER 72	Federal Power Commission, *A Review of Consolidated Edison Company 1972 Summer Power Supply Problems and Twenty-Year Expansion Plans,* Sept. 1972
FPC NPF 65	Federal Power Commission, *Northeast Power Failure, November 9 and 10, 1965,* Dec. 6, 1965
FPC PFA 66	Federal Power Commission, *Continuing Activities of the Federal Power Commission in Power Failure Analysis,* Apr. 1966
FPC PFI 66	Federal Power Commission, *Major Power Failure Investigation,* Nov. 1966
FPC PPF-1 67	Federal Power Commission, *Prevention of Power Failures, Volume I—Report of the Commission,* July 1967
FPC PPF-2 67	Federal Power Commission, *Prevention of Power Failures, Volume II—Advisory Committee Report, Reliability of Electric Bulk Power Supply,* June 1967
FPC PPF-3 67	Federal Power Commission, *Prevention of Power Failures, Volume III—Studies of the Task Groups on the Northeast Power Interruption,* June 1967

Table O-1.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: Control Center*

Recommended item	Reference	Con Edison action	FERC staff comment
Replacement of dual-scale frequency meters with 2 separate instruments	FPC NPF 65, 1st paragraph, p. 9	Con Edison's dual-scale frequency meters were changed to individual meters after 1965.	Company has complied fully.
Establishment of system security center	FPC PFA 66, 2d full paragraph, p. 16; FPC PPF-1 67, rec. 14, 15, and 17, p. 91; FPC PPF-3 67, rec. 8, p. 114	Energy control center was built in 1963. First computer was put into service in 1966. Cathode ray tube (CRT) monitors and contingency analysis computer program were added in 1973. The load-shedding and voltage-reduction panels were installed in 1967. Telemetering and a supervisory display were added in 1972. A high-speed printer to NYPP was installed in April 1977. Establishment of the NYPP pool control center relieved Con Edison energy control center of responsibility for economic dispatch and external system security analysis.	Con Edison control center has improved progressively, consistent with technological development.
Auxiliary power for control center communications and instrumentation	FPC PFA 66, item (b), p. 15; FPC PFI 66, 2d paragraph, p. 9; FPC PPF-1 67, rec. 16, p. 91	Control center is located in the same complex as West 65th Street Substation. Normal supply is from this substation. First emergency supply is from an internal combustion unit at complex. Second emergency supply is from gas-turbine generation via 2 feeders from 59th Street Substation.	Company has complied fully.
Dissemination of emergency information to the public and civil authorities	FPC PFA 66, 1st full paragraph, p. 16	Con Edison has an established program for requesting customer assistance in reducing load where the need is known in advance and for notification of civil authorities during emergencies: Emergency notification procedures are being reviewed.	Con Edison's procedure was inadequate on July 13, 1977.
Higher priority for service reliability than for economics where there is conflict	FPC NPF 65, rec. 8, p. 44	NYPP economic dispatch program was provided with a security override package but July 13, 1977, incident revealed need for automatic quick update feature. All NYPP companies are working with pool personnel to resolve this.	Compliance is in progress.

Note: NYPP = New York Power Pool; rec. = recommendation.

Table O-2.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: Selection, Training, and Supervision of Personnel*

Recommended item	Reference	Con Edison action	FERC staff comment
Thorough training of plant personnel	FPC NPF 65, rec. 12, p. 44	In 1965 8 plant training courses, which included a fossil-plant simulator, were in existence. Since 1965 over 70 plant training courses have been developed and emergency procedures added to plant simulator.	Performance is superior. Other systems send their plant personnel to Con Edison for training.
Formal training of control center personnel	FPC PPF-1 67, rec. 23, p. 92	Formal training consists of short course at Iowa State University. Informal training consists of completion of distribution splicing, network protector and switching courses, observation of substation switching, and annual visits to NYPP control center. Ladder system of progress requires 10 to 12 years of on-job training to reach top level of system operator.	More agressive effort is needed. Con Edison should seek assistance from qualified training consultants.

Note: NYPP = New York Power Pool; rec.= recommendation.

Table O-3.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: Operating Reserves*

Recommended item	Reference	Con Edison action	FERC staff comment
Fast response of spinning reserve	FPC NPF 65, rec. 9, p. 44; FPC PPF-1 67, rec. 18, p. 91	Con Edison plans to perform monthly fast-load-pickup tests on all units as result of July 13, 1977, power failure.	NPCC and NYPP reserve criteria evolved from this recommendation. Reserve generation was not available on July 13, 1977, in time and amount anticipated, although response exceeded NYPP reserve requirement.
Adequate amount of operating reserves	FPC NPF 65, rec. 7, p. 44	Since July 13, 1977, Con Edison has increased ratio of in-city generation to total system load during storm watches.	Reserve situation needs to be reviewed in light of heavy imports of economy power.[1]
Uniform distribution of spinning reserve	FPC PPF-3 67, rec. 6, p. 113	After 1965, Con Edison adhered to NYPP criteria. All machines are under governor control and maintain 10 percent or less of required spinning reserve.	Company has complied fully.

Note: NPCC = Northeast Power Coordinating Council; NYPP = New York Power Pool; rec. = recommendation.

[1] These actions may reduce economy of power supply under statewide economic dispatch.

Table O-4.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: Design and Operation of Protective Systems*

Recommended item	Reference	Con Edison action	FERC staff comment
Frequent review of relay protection	FPC NPF 65, rec. 6, p. 44; FPC PPF-1 67, rec. 13, p. 90	Since July 13, 1977, Con Edison has modified test procedures to test protective schemes as systems in addition to testing individual components. Since 1970, testing is performed at least annually and status is monitored each month by computer.	Company has complied fully.
Flexibility of switching arrangements to maximize reliability	FPC PPF-1 67, rec. 9 p. 90; NYPSC CED-2 77, rec. 17 p. v-6	Conversion of some 138-kV lines to 345-kV is in progress, and installation of underground direct current circuits is under consideration. Circuit-breaker arrangements at Buchanan and Pleasant Valley Substations are being reviewed, and changes are expected.	Diversity of line routing and switching arrangements is difficult on the Con Edison System because of geographical limitations.

Note: rec. = recommendation.

Table O-5.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: Emergency Planning and Operation*

Recommended item	Reference	Con Edison action	FERC staff comment
Auxiliary power for black start of powerplants	FPC NPF 65, rec. 13, p. 44	After 1965, recommendation was satisfied by installation of diesels and gas turbines at powerplants.	Company has complied fully.
Auxiliary power for safe run-down of powerplants	FPC PFI 66, last paragraph, p. 9; FPC PPF-1 67, rec. 21, p. 92	Auxiliary power was installed at all generating stations after 1965. All diesels operated and all plant equipment was shut down without damage July 13, 1977.	Company has complied fully.
Assisting customers with critical loads in having standby auxiliary power	FPC PPF-1 67, rec. 30, p. 93	The customer has ultimate responsibility for providing standby emergency power but Con Edison has an annual program of reviewing customer emergency needs.	Company has complied fully.
Auxiliary power for underground transit system	FPC PPF-1 67, column 1, last paragraph, p. 14	Gas turbines were installed at the 59th Street and 74th Street powerplants primarily for black-start purposes, but they also can furnish power to permit the BMT and IRT trains to reach the next station.	Compliance is complete. There was no case where any trains were stranded July 13, 1977. However, during the blackout the BMT and IRT trains, operating on 25 Hz, obtained power from unit No. 13 at West 59th Street Station.
Employment of compensating devices (capacitors and reactors)	FPC PFI 66, 2d paragraph, p. 11	Con Edison employes manually switched reactors in underground system. As a result of slow restoration, partially because of irregular voltage patterns on July 13, 1977, Con Edison is considering permanent installation of reactors and automatic switching of capacitors.[1]	Because of unique electrical characteristics of the Con Edison system, automatic control of compensating devices appears to be necessary.
Coordinated program of automatic load shedding	FPC NPF 65, rec. 11, p. 44; FPC PPF-1 67, rec. 19, p. 91; FPC PPF-3 67, rec. 9, p. 114	In 1967, Con Edison implemented program to shed up to 50 percent of load in 5 steps of generally increasing magnitude. This is coordinated throughout NPCC.[2]	Network electrical characteristics prevented the automatic load shedding from fulfilling its purpose on July 13, 1977.
Exemption of critical loads from load shedding	FPC PPF-3 67, rec. 13, p. 114	Since 1967, great effort has been put into coordinating selection of loads for load-shedding application with city and state authorities.[3]	Compliance is as complete as possible for large metropolitan area.
Maximization of generators on automatic voltage regulation	FPC PPF-3 67, rec. 7, p. 113	Since 1965, generator voltage regulators are kept in service at all times unless regulators develop trouble.[4]	Company has complied fully.

Note: BMT = Brooklyn-Manhattan Transit Corp.; IRT = Interboro Rapid Transit; NPCC = Northeast Power Coordinating Council; rec. = recommendation.

[1] Compensating devices are a coarse type of voltage control, and fine tuning is done in the Con Edison system with generator voltage regulator control.

[2] Consideration is being given to increasing the total amount of load shedding from 50 to 60 percent of load.

[3] Load is shed in the Manhattan area on the last step of automatic load shedding.

[4] All generator units were on automatic voltage regulator control July 13, 1977.

Table O-6.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: System Planning*

Recommended item	Reference	Con Edison action	FERC staff comment
Extend period of long-range planning	FPC PFI 66, last paragraph, p. 13	Since 1972, long-range plans covering 15-year period are submitted formally to NYPSC each year in compliance with NYPSC Order No. 149-B.	Company has complied fully.
Use of detailed load forecasting methodology	FPC PPF-1 67, rec. 6, p. 89; FPC CER 69, rec. 4, p. 77	Since about 1972, Con Edison employs 3 separate sophisticated load-forecast techniques as a cross-check. Details are reported to NYPSC annually in 149-B report.	Company has complied fully.
Stability of networks under severe disturbances	FPC NPF 65, rec. 5, p. 44; FPC PPF-1 67, rec. 5, p. 89; PFC PPF-3 67, recs. 2, 3, and 4, p. 113; FPC CER 72, 1st paragraph, p. 13	Since about 1967, criteria listed in this recommendation were incorporated in the NPCC design criteria and Con Edison follows these criteria in preplanning its system for possible but improbable contingencies.	Company has complied fully.
Installation of sufficient generating capacity so that each of the four northeast areas meets a loss of load probability of no more than 1 day in 10 years	FPC PPF-3 67, rec. 1, p. 113	Since about 1972, upstate and southeastern New York areas, formerly distinct, have been combined and superseded by formation of NYPP. NYPP is sufficiently coordinated to be considered as single area, and as a single area does meet criterion of 1 day in 10 years.	Company has complied fully.
Construction of 500-kV interconnection between Con Edison and PJM by 1968	FPC PFA 66, rec. 3, p. 14	Company has constructed 500-kV interconnection between Con Edison's Ramapo Substation and PJM substation at Branchburg.[1]	Company has complied fully.
Construction of 345-kV line from Brooklyn to Staten Island	FPC PFA 66, rec. 5, p. 15	Construction of another line is contingent upon the completion by PASNY of a coal- and garbage-burning plant on Staten Island now scheduled for 1982.[2]	Progress is satisfactory.
Construction of high-voltage tie through upstate New York to Quebec Hydro by 1971	FPC PFA 66, rec. 15, p. 15	765-kV/735-kV intertie is under construction by PASNY and Quebec Hydro. Con Edison expects to receive 600 of 800 MW of Quebec diversity power. Intertie is scheduled for completion in 1978.	Approval is required by NYPSC before service can commence at 765-kV/735-kV intertie, although service can commence initially at 345 kV.
Transfer capability into the Con Edison system of at least 25 percent of peak load after allowance for scheduled transfers	FPC CER 69, rec. 6, p. 77; FPC CER 72, 2d paragraph, p. 13	Calculations for the summer of 1977 indicate a percentage transmission reserve of 23.5 to 26.5 percent. It has been in this range since 1972.	Company has complied fully for now.
Reactive power supply planning	FPC PPF-3 67, 2d column, last paragraph, p. 76	Conventional load flow analysis of reactive supply as a special item has been done since 1967. In conjunction with the University of Texas a reactive optimization program has been under development the last 2 years.	Company has complied fully for now. Data need continuous updating.
Investigation of value of high-voltage d.c. transmission	FPC CER 69, rec. 7, p. 78	Con Edison has conducted this investigation since 1963. Parallel operation of d.c. and a.c. circuits is extremely complex. Con Edison has actively participated in research in this area. Test d.c. installation is scheduled for service in 1978 at the Astoria plant.	Company has complied fully.
Close coordination of electric facilities with neighboring systems	FPC PPF-1 67, recs. 1 and 2, p. 4; FPC CER 69, rec. 10, p. 78	Since about 1972, in conjunction with the formation of NYPP, coordinated planning for State of New York has been implemented. The seven investor-owned members of NYPP have petitioned to acquire stock in a statewide generating company, which will build and operate plants scheduled for service after mid-1980's.	Company has complied fully.

See footnotes at end of table.

Table O-6.—*Actions Taken by Con Edison Related to Recommendations, Before July 13, 1977: System Planning*—Concluded

Recommended item	Reference	Con Edison action	FERC staff comment
Evaluate high-voltage underwater tie from Long Island to New England	FPC CER 69, 3d paragraph, p. 64	Tie across Long Island Sound would be the responsibility of Long Island Lighting Co. and Connecticut Light and Power Co. This tie poses serious technical difficulties.	Recommendation does not apply to Con Edison.
Increase tie capability between Con Edison and PJM	FPC CER 69, 4th paragraph, p. 64	This was accomplished in 1972 with completion of Ramapo to Branchburg 500-kV tie and Hudson to Farragut 345-kV tie. In addition, 345-kV Ramapo to Waldwick tie was completed.	Company has complied fully. Continuous evaluation of tie capability to PJM is needed.
Construction of 345-kV Dunwoodie to Glenwood tie with Long Island Lighting Co. by 1975	FPC CER 72, 3d paragraph, p. 9	Line is under construction and is expected to be complete in 1978.	Company is nearing full compliance.
Strong preventive maintenance program	FPC PPF-1 67, rec. 24, p. 93	A great deal of overdue maintenance was performed between 1971 and 1973, and strong scheduled preventive maintenance program was established.	Company will have complied fully, if present program is continued. Equipment availability has been greatly improved since 1971.
Coordination of maintenance with system operations	FPC PPF-1 67, rec. 26, p. 93	Testing and maintenance is scheduled through the sequence group at energy control center and has been since 1965.	Company has complied fully.

Note: NPCC = Northeast Power Coordinating Council; NYPP = New York Power Pool; NYPSC = New York Public Service Commission; PASNY = Power Authority of the State of New York; PJM = Pennsylvania-New Jersey-Maryland Interconnection; rec. = recommendation.

[1] Line was delayed from 1968 to 1972 because of right-of-way acquisition problems in New Jersey.

[2] An initial 345-kV underground double-circuit line from Brooklyn to Staten Island was placed in service during summer 1967.

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