U. S. NUCLEAR REGULATORY COMMISSION
REGION I

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Licensee: Public Service Company of New Hampshire, New Hampshire Yankee (NHY) Division

Facility: Seabrook Station, Seabrook, New Hampshire

Dates: June 28 to July 5, 1991

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SCOPE

Inspection of the June 27, 1991 loss of power to on-site busses and the consequent turbine and reactor trips.

OVERVIEW

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OVERVIEW

Event: A manufacturing defect in a relay casing caused Out-Of-Step Relay actuation which resulted in a loss of power to all on-site electrical busses and a plant trip from 100% power. The Emergency Diesel Generators started and powered the on-site emergency busses, and off-site power was restored to on-site busses in about 20 minutes. Primary system parameters remained within the normal post-trip range.

Operations: Management oversight, control room command and control, auxiliary operator response, and fire fighter performance were excellent. A lack of operator knowledge of the instrument air header pressure needed to operate an atmospheric steam dump valve in automatic may have resulted in lifting a steam generator safety-relief valve when a reactor coolant pump was started. Systems responded as designed with minor exceptions such as the momentary loss of the Class 1E uninterruptable power supply.

Radiological Controls: Response to radiation monitor alarms was good. Calculations of potential unmonitored releases were made in accordance with procedures. No abnormal radiation releases occurred as a result of this event.

Maintenance/Surveillance: The surveillance which initiated the event was conducted by contractor personnel under a formal interface agreement. New Hampshire Yankee oversight was extensive. No procedural inadequacy was identified.

Security: Response to the event was good; all security systems performed as required.

Emergency Preparedness: The event was classified and reported as required. Informal notifications of neighboring communities were timely and appropriate.

Engineering/Technical Support: The relay system functioned as designed, however, vulnerabilities in the design were identified. Procurement of the relay casing was standard for non-class 1E commercial grade electrical components. Interim removal of the Out-Of-Step Relay from service to prevent recurrence of the event was appropriate. Licensee technical reviews of system and equipment responses were good.

Quality Assurance/Safety Verification: An excellent licensee event evaluation was conducted. Additional areas for further evaluations and enhancements, especially in the area of protective relaying, were identified.

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DETAILS

1.0 EVENT DESCRIPTION

On June 27, 1991, routine scheduled 345 kV switchyard relay testing was being conducted by New England Power Service Company (NEPSCO) in the Relay Room. The unit was operating at 100% steady state power. At approximately 1:34 p.m., 345 kV Failure Relay 50BF-2H for Breaker 11 was returned to service. Due to a manufacturing error in the relay housing contact block assembly, arcing occurred across the contacts of the knife switch used to return Relay 50BF-2H to service. At the same time, 345 kV Breakers 11 and 163 opened. As designed, no relay signal was generated to open the Unit Auxiliary Transformer (UAT) supply breakers to the 4160 V busses. That prevented an automatic transfer of off-site power to supply station loads via the Reserve Auxiliary Transformers (RATs). All site electrical busses were deenergized, and the turbine and reactor tripped. Forced cooling flow through the reactor core was lost due to loss of power to the Reactor Coolant Pumps (RCPs).

Both Emergency Diesel-Generators (EDGs) automatically started and energized Emergency Busses E5 and E6. The operators initiated the Emergency Operating Procedures (EOPs). The Main Steam Isolation Valves were closed to prevent overpressurizing and overheating the condenser. In about 20 minutes, Busses 1, 2, 3 and 4 were energized from the RATs and equipment was restarted. When Reactor Coolant Pump RCP-C was started, a safety-relief valve on Steam Generator SG-C opened. The unit was stabilized in Operational Mode 3, Hot Standby, with RCP-C providing forced circulation cooling.

Two hours after the reactor trip, a four-hour notification was made reporting the reactor protection system activation and the activation of four Engineered Safety Feature (ESF) systems.

A Sequence of Events is provided as Attachment 1 to this report.

2.0 OPERATIONS

2.1 Operator Response

The inspector observed the operators' response to the event and later reviewed operating logs, alarm printouts, and the event evaluation report. Also, discussions were held with Operations and Technical Support Department personnel. At the time of the trip, the Unit Shift Superintendent (USS) entered Emergency Operating Procedure E-O, "Reactor Trip or Safety Injection," and at Step 4 transitioned to ES-0.1, "Reactor Trip Response." After completion of ES-0.1, Normal Operating Procedure OS-1000.11, "Post Trip to Hot Standby," was entered.

Immediately after the trip, Operations Department management and off-shift licensed operators reported to the Main Control Room (MCR) to assist in plant recovery. Auxiliary Operators (AOs) assigned to the primary auxiliary building reported to the turbine building immediately. Additional AOs from the relief and training shifts were dispatched to assist with plant recovery. Radio communications between the Main Control Room and the AOs were lost temporarily, but did not affect the recovery due to the availability of phone communications and the absence of equipment and flow noise in the turbine building. Licensee evaluation found that the AOs experienced difficulty with the level of emergency lighting in the turbine building, due to the contrast from bright sunshine outside the building. No impact on the response to this event resulted. NHY plans to review turbine building emergency lighting further.

After the trip, the Shift Superintendent quickly concluded that off-site power was available, and confirmed that with the load dispatcher within five minutes after the trip. The Unit Shift Supervisor (USS) implemented the Emergency Operating Procedure (EOP) which verified that the reactor was subcritical and that the emergency electrical busses were energized. After establishing control of pressurizer level and pressure, the USS stabilized plant heat removal via the steam generators before restoring non-vital electrical loads. The completion of the EOPs was not time-critical because primary pressures and temperatures were in the normal post-trip range, and the USS proceeded deliberately toward restoring the non-vital busses.

The Operations Manager was present in the Main Control Room and provided an oversight function for plant recovery. The Operations Manager directed that the Main Steam Isolation Valves (MSIVs) be shut approximately fifteen minutes into the event. This direction was not specified by the EOPs and was based on preventing overpressurization of the condenser. Such actions are permitted by the Station Management Manual Chapter 1.0, "Station Policies," to prevent damage to major equipment. NRC review found this specific action appropriate under the circumstances, but noted that it also appeared to be appropriate to incorporate such provisions in the EOPs involved.

Prior to restoring power to the non-vital busses, Service Air (SA) Compressors 1A and 1B were started. Instrument Air (IA)/SA Isolation Valves 1-SA-V92 and 93 were opened by applying bottled nitrogen to the bottom of the air operators. IA header pressure dropped from 48 psig to approximately 43 psig when 1-SA-V92 and 93 opened.

Two minutes later, after discussing expected plant responses and verifying that Atmospheric Steam Dump Valve ASDV-C was in automatic with a setpoint of 1125 psig and IA header pressure was between 60 and 70 psig, the Senior Control Room Operator started RCP-C. Pressure in Steam Generator SG-C increased approximately 85 psig as expected. ASDV-C did not modulate, possibly due to inadequate IA header pressure. A safety valve on SG-C opened to control steam header pressure and a fire alarm was received from the East Pipe Chase. The Control Room Operator (CRO) closed ASDV-C and placed its control switch in POSITION MAINTAIN, as required by Abnormal Procedure OS-1200.00, "Response to Fire or Fire Alarm Actuation." Fire fighters were dispatched to the East Pipe Chase.

When the firefighters arrived at the East Pipe Chase, they informed the Main Control Room that a safety valve had lifted on SG-C. The Control Room Operator remotely opened ASDV-C using the backup nitrogen bottles. The reduction in steam line pressure allowed by opening ASDV-C allowed the SG-C safety valve to close.

The restoration of normal electrical and decay heat removal lineups and primary system forced circulation were then completed.

The inspector assessed the performance of the Operations Department as controlled and professional. Excellent command and control was demonstrated. Responsibilities, lines of communication, and the chain of command were well-understood and resulted in a controlled response.

During the trip review meeting three hours after the trip, the Plant Manager directed that managers adhere to station overtime priorities in scheduling personnel for trip follow-up. The inspector observed the implementation of the overtime directive in that the investigation team was cognizant of their work hour limit and put the investigation on hold about 11:00 p.m. on June 27. The inspector concluded that the station appropriately controlled safety-related work hours in responding to this event.

During the event several fire alarms were received in the Main Control Room. A fire alarm in the Diesel Building was immediately verified locally to have been caused by a known condition related to the Emergency Diesel Generator EDG-A supercharger. A fire alarm in the East Pipe Chase was responded to in accordance with Operations Procedure OS-1200.00, "Response to Fire or Fire Alarm Actuation." The firefighters who responded to the alarm did not enter the chase due to the reported lifting of a safety valve for SG-C. Lifting of that valve was also known to activate nearby fire detectors. After restoration of the non-vital busses, verification of proper fire system status was made by the fire fighters.

The inspector toured the Diesel Generator Building, Control Building, Spent Fuel Building, Transformer Yard, and Primary Auxiliary Building during the event. The inspector determined that personnel and Fire Protection System responses were proper, and noted that the causes of the fire alarms which occurred during the starting of EDG-1A and release of steam in the pipe chases were known by the operators and fire fighters. The inspector concluded that the compensatory measures in place are adequate pending full resolution of these items (e.g., repair of the small leak in the EDG-1A supercharger under Work Request 89W005391.)

2.2 Equipment Response

The inspector reviewed the alarm printout, the event evaluation, and past NRC Inspection Reports, and held discussions with Operations and Technical Support Department personnel. In general, the equipment performed as designed.

The response of the electrical relay circuits which opened 345 kV Breakers 11 and 163 is described in Section 7.0 of this report. When 345 kV Breakers 11 and 163 opened, the Early Valve Actuation and Power Load Unbalance Protective Features in the Electro-Hydraulic Control System tripped the turbine. Rapid closure of the turbine control valves caused a steam line pressure spike which actuated the steam generator high-high level (P-14) turbine trip signal. (This phenomenon has been experienced in previous trips. Actuation of the P-14 signal is caused by ringing of the differential pressure transmitter. The licensee is evaluating a modification to eliminate this characteristic.) The main generator breaker opened, less than 0.5 seconds following the turbine trip, on closure of the turbine trip throttle valves.

All station electrical busses were deenergized. All but one of the Uninterruptable Power Supplies (UPSs) transferred to their DC power supply. The UPS-1E inverter momentarily deenergized before switching to its DC power supply, which caused a Control Building Air Handling Recirculation (CBA) and Containment Ventilation Isolation (CVI) Train "A" Engineered Safety Features (ESF) actuation signal. No ventilation line-up changes resulted.

The reactor tripped on the turbine trip signal. An additional reactor trip signal was generated by the nuclear instrument power range rate trip caused by rods falling into the core when the rod control motor-generator sets were deenergized.

The steam dump valves armed and started to open when turbine impulse pressure decreased rapidly, activating the C-7A signal. The circulating water pump breakers opened due to the undervoltage on the non-vital busses and removed the C-9 permissive for steam dump operation, causing the steam dumps to shut.

The emergency diesel generators sensed an undervoltage on the emergency busses, started, and loaded within ten seconds. Loads sequenced onto the emergency busses normally. The diesel-driven fire pump started on low fire protection header pressure due to loss of power to the motor-driven fire pump being used for the fire header flushing which was in progress. The Atmospheric Steam Dump Valves (ASDVs) opened to limit the main steam line pressure and to remove decay heat with the reactor coolant system in natural circulation flow.

Power was restored through the Reserve Auxiliary Transformers (RATs) to the non-vital busses and equipment was loaded onto the busses. When Reactor Coolant Pump RCP-C was started, a safety-relief valve on SG-C lifted when ASDV-C did not modulate to control steam header pressure. ASDV-C was opened, pressure decreased in SG-C, and the safety-relief valve reseated.

The ASDVs are air-operated valves with nitrogen backup provided by bottled gas. The switch positions for each valve are MODULATE, CLOSED, POSITION MAINTAIN, and OPEN. In the MODULATE position the valves modulate to control a steam pressure, which is set by output controller. In the CLOSE position the valve fully closes. In the OPEN position the valve fully opens. The POSITION MAINTAIN position is used to hold an ASDV in an intermediate position after jogging the ASDV by momentarily selecting the OPEN or CLOSE position. For ASDV-C, when the CLOSE or OPEN positions are selected, nitrogen gas is supplied as a back-up to instrument air. Nitrogen back-up is not provided in the MODULATE mode.

The Technical Support Department determined from quarterly testing of ASDVs that an air pressure of 60 psig at the valve positioner is required to open the valves. When RCP-C was started, IA air header pressure as indicated in the Main Control Room was between 60 psig and 70 psig and may have been insufficient to open ASDV-C. When the OPEN position was selected, nitrogen pressure opened the valve. The Operations Department planned to provide operators with procedural guidance for the acceptable IA header pressure required for operations of ASDVs in MODULATE.

The five safety-relief valves on the steam header to SG-C are set to lift at different pressures. The setpoints for these valves follow:

Valve	Setpoint
MS-V 36	1185 psig +/- 10%
MS-V 37	1203 psig +/- 10%
MS-V 38	1220 psig +/- 10%
MS-V 39	1238 psig +/- 10%
MS-V 40	1255 psig +/- 10%

Following the start of RCP-C, MS-V 38 lifted. The Technical Support Department determined that this was an expected plant response, based on analysis of previous thermal hydraulic transients which occurred with MSIVs shut. During hot functional testing in February 1987, relief valves were lifted on an isolated main steam line. Since the relief valves with lower setpoints did not lift, they were removed and their lift setpoints were verified as being correctly set. The Technical Support Department determined that, in steam lines with an MSIV shut, safety valves can lift in order of descending lift setpoints since the pressure surge appears to be amplified by reflection off the MSIV. (The previous events, the licensee's analysis, and NRC assessments are documented in NRC Inspection Reports 50-443/91-01, 50-443/87-16, and 50-443/87-02.)

Licensee review of the pressure surge created by the starting of RCP-C was accomplished by comparing changes in Loop "C" reactor coolant cold leg temperature, steam generator pressure, and the differential pressure across the steam flow detector nozzle. The magnitude of the pressure surge, which reached approximately 1210 psig, corresponded to the change in plant parameters. The pressure also corresponded to the lift setpoint of MS-V 38 which, according to licensee analysis, opened and reduced steam header pressure below the lift setpoints of MS-V 36 and V 37.

The inspector discussed the characteristics of pressure transients in isolated main steam headers, reviewed the licensee's analysis of the February 1987 event, and independently calculated the expected main steam line pressure change. The inspector concluded that the lifting of MS-V 38 was a typical system response to starting a RCP in a loop with an isolated steam generator and an inoperable ASDV. The Operations Department committed to provide operators with additional guidance on what actions to take to prevent challenging safety systems when an RCP is started.

The block valve to Feedwater Regulating Valve FRV-B did not operate due to a blown fuse in its motor-operator control circuit, and was closed manually. The fuse was replaced and the valve was returned to operability prior to restart. All other equipment operated normally during the plant recovery.

3.0 RADIOLOGICAL CONTROLS

The inspector reviewed the response of radiation monitoring equipment to the loss of power event, and evaluated the Chemistry Department's calculations for unmonitored radioactive releases.

All but two Technical Specification radiation monitors are powered from the Emergency Busses. The two monitors powered from non-vital busses, Containment Atmosphere Monitor RM-6526 and Steam Generator Blowdown Flash Tank Discharge Monitor RM-6519, were deenergized for nineteen minutes. Consequently, Steam Generator blowdown flow to the ocean was isolated.

The radiation monitors powered from the emergency bus were deenergized for less than a minute when the emergency busses were deenergized and the Emergency Diesel-Generators started and loaded. The Radiation Display and Monitoring System was inoperable for the first four minutes of the event due to the loss of a computer data link. The momentary loss of the detectors and monitoring systems were noted, and had no effect on the monitoring of radioactive releases.

Technical Specification radiation monitors are powered from Uninterruptable Power Supplies UPS-1-1E and UPS-1-1F. UPS-1-1F transferred from its AC source to its DC source due to high AC voltage. UPS-1-1E lost output voltage momentarily during the transfer from its AC source to its DC source. During the loss of power, the following radiation monitors were momentarily deenergized:

RM-RM-6506A	East Air Intake to the Control Building
RM-RM-6507A	West Air Intake to the Control Building
RM-RM-6528	Wide Range Gas Monitor
RM-RM-6576A	Post LOCA Monitor
RM-RM-6536A	Containment Refueling Crane
RM-RM-6527A	Containment Purge

As a result, indications were lost momentarily and two Engineering Safety Feature (ESF) actuation signals were initiated. RM-6506A and 6507A initiated a Control Building Air (CBA) Handling System Recirculation signal. By design, the Control Building Air Handling Ventilation System restarts in the recirculation mode after loss of an emergency bus. Therefore, no component actuation resulted from this actuation signal.

RM-6527A and 6536A initiated a Containment Ventilation Isolation Signal. No component actuation occurred since all components were in the containment ventilation isolation line-up for power operation.

Radiation Monitor RM-6504 for the waste gas compressor discharge alarmed approximately fifteen minutes after power was lost to the waste gas compressors. The alarm cleared two minutes after power was restored to the waste gas compressor, restoring flow in the system. The alarm was caused by the loss of flow and cleared soon after flow was reestablished. No increase was noted in either the carbon delay bed radiation monitor (RM-6503), which is upstream of RM-6504, or in the Wide Range Gas Monitor. The Waste Gas System was in the recycle mode and was not releasing to the plant stack at the time of the loss of power.

The radiation monitor on the condenser air evacuation path alarmed five minutes after condenser vacuum was broken. An air evacuation line sample was taken, in accordance with procedure CS-0917.03, "Unmonitored Plant Releases," and evaluated for particulate, noble gas, and iodine activity. All measurements were below minimum detectable. The hotwell was sampled and determined to contain below minimum detectable activity. Based on the results of the samples, no activity was released. Review of the detector response by the Chemistry Department attributed the alarm to the increased temperature and steam in the condenser resulting from the loss of vacuum.

The release of steam from the turbine-driven emergency feedwater pump, atmospheric steam dumps, and steam generator safety-relief valve were evaluated in accordance with procedure CS-0917.03. No radioactivity was measured and the unmonitored release was calculated to be zero. The inspector reviewed the completed procedures and sample results, and concurred in the results.

The inspector determined that there were minimal challenges to the Chemistry and Radiological Control Department and that responses to alarms were in accordance with established procedures. The inspector noted that the spurious ESF actuation signals caused by radiation monitors did not cause component actuations and had no effect on plant recovery. The inspector concluded that the Chemistry and Radiological Control Departments responded well to the event.

4.0 MAINTENANCE/SURVEILLANCE

The inspector held discussions with the Electrical Maintenance Department Supervisor and a Shift Superintendent, reviewed preventive and corrective maintenance documentation for work performed on the day of the transient and prior work on similar 345 kV relays, and walked-down the relay configuration in the Relay Room.

The 345 kV relaying system surveillance which initiated the event was performed under a 1988 interface agreement with relaying organizations which included NEPSCO (the New England Power Service Company). That interface agreement detailed the administrative and procedural requirements for responsible work groups. The process for performing work on the 345 kV relay system included scheduling, tagging, prejob walk-through, station authorizations, and documentation. The Maintenance Department work control process supported and enhanced the guidelines established in the interface agreement. The station restricts 345 kV relay tasks: only one Repetitive Task Sheet (RTS) can be in progress at a time and must be completed by the end of the day or cleared. Also, station personnel must perform a prejob walk-through and close-out each RTS done by the switchyard relay group.

The inspector discussed the qualifications of the NEPSCO technicians with the Electrical Maintenance Department Supervisor. The inspector concluded that the relay group was qualified to perform the surveillance and that appropriate station oversight was undertaken to assure quality performance of 345 kV relay work.

5.0 SECURITY

The inspector held discussions with a New Hampshire Yankee Security Supervisor, a Shift Superintendent, and the Station Manager, and reviewed security logs to determine the impact of the electrical transient on site security.

A momentary loss of power to the security systems occurred while the power supply was automatically transferred following the initial transient. Security personnel heard the public address announcement directed to all site personnel by the control room following the turbine/reactor trip and responded in accordance with site security procedures.

The inspector verified that, for any degradation of security due to the electrical transient, adequate compensatory actions were taken. The inspector confirmed that all security communications equipment and protected area personnel door access methods were unaffected. Security members on patrol noted no problems with emergency lighting.

The inspector concluded that security's response to the event was proper and that all systems performed their required functions.

6.0 EMERGENCY PREPAREDNESS

6.1 Classification of Event

The inspector held discussions with the senior plant managers, operations managers, and the Shift Superintendent involved in the initial event classification or in the review of that classification. The inspector reviewed the station's emergency classification procedure and discussed operator training on emergency classification with a member of the training staff.

The Shift Superintendent indicated that, following his initial plant trip assessment and verification of critical safety function status, contact was made with the system load dispatcher to confirm the status of the off-site power. The dispatcher informed the Shift Superintendent that the grid was not degraded and that Seabrook Station could close 345 kV Breakers 11 and 163. The decision made several minutes into the transient was that the event did not fall into the initiating condition for an Unusual Event as specified in the Production Emergency Response manual, Chapter E1.1, "Classification of Emergencies." The condition that "Bus E5 and E6 cannot be powered from an offsite source" was evaluated by the licensee as not being met since, by manual breaker operation, Busses E5 and E6 could be powered from the station ring bus.

The Shift Superintendent, in consultation with the Operations Manager, established a contingency plan to upgrade immediately to an Unusual Event if a breaker failed to close onto the grid during the emergency procedure recovery sequence. The Shift Superintendent concluded, within minutes, that the probable cause of the transient was the relay testing. The Shift Superintendent knew that following the procedural guidance in the Emergency Operating Procedures would stabilize plant conditions and restore off-site power. Since the bus transfer to the grid was successful, the event was evaluated as requiring a 10 CFR 50.72b.2.ii four-hour report. The training crew Shift Superintendent gathered the technical data for the four-hour report, which was made approximately two hours after the initiating event. An ENS update was made about eight hours after the initial four-hour report when the relay manufacturing defect was identified as the root cause of the transient.

The inspector attended the trip review meeting and observed senior managers ask all station personnel present if anyone had information which would alter the classification; no additional information was presented.

The inspector concluded that the initial classification was in accordance with the station's emergency procedures. When the classification was made, the diesel-generators had been running loaded for several minutes and the initial plant response was in accordance with design. The inspector noted that the pre-establishment of a contingency classification was prudent. The inspector verified that the classification of the event was consistent with formal station operator training.

The inspector concluded that, based upon the information available to the Shift Superintendent and Operations Managers during the first few minutes of the event, the event classification was in accordance with facility procedures.

Whether an unplanned interruption of off-site power to on-site busses should be classified as an Unusual Event to better assure appropriate awareness on the part of facility management, State officials, and the NRC was identified for further NRC evaluation.

6.2 Communications

The inspector observed communications in the Main Control Room during the trip recovery, discussed the response of Corporate Communications during the event with department representatives, and reviewed telephone logs from Corporate Communications and Community Relations. Also, the inspector talked with senior licensee management regarding incoming and outgoing communications, and with rumor control, and reviewed prior correspondence from the local community and local newspaper articles which addressed the importance of timely notification of the surrounding communities for emergency and non-emergency events.

A partial listing of the communications that occurred immediately following the transient was compiled with the approximate times and sequence based on numerous discussions. That listing, provided in Attachment 2, was prepared to provide insight into the communications that occur routinely following an event that has the potential for heightened public interest or awareness. In addition, Emergency Management Directors and Town Officials in seventeen New Hampshire and six Massachusetts communities were contacted by the Community Relations Department under the licensee's good neighbor notification process. Good neighbor notification is a process for notifying local and State officials of notable Seabrook activities that do not involve a response under the Emergency Plan.

The inspector assessed the sequence, timeliness, and scope of the calls made during the first few hours of this event, which was not classified as an emergency situation. The inspector concluded that the communications were timely and the scope was appropriate, and that the three calls made to the surrounding communities police/fire departments served to adequately alert the local communities.

The station's good neighbor policy has evolved from an informal process to a formal procedure under final review. The implementation of this policy during this event was focused on promptly notifying the nearby fire/police departments, which needed the information in order to respond to inquiries from the local populace. Since the plant was stable, the value of continuing notification was for information only, and not to procure resources or assistance. The inspector concluded that these communications were appropriate.

7.0 ENGINEERING/TECHNICAL SUPPORT

7.1 345 kV System Description

The 345 KV switchyard supplies off-site power to Seabrook Station. The electrical configuration of the 345 kV switchyard has a "breaker and a half" arrangement as shown in Attachment 3. The 345 kV switchyard has eight circuit breakers, three transmission line connections, a unit main generator step-up transformer (GSU) connection, and two bus connections to the Reserve Auxiliary Transformers (RATs). The 345 kV switchyard breakers' control switches, alarms, and monitoring devices are located in the Main Control Room, and the protective relays, specific alarms, and local controls are located in the unit's Relay Room.

Two Unit Auxiliary Transformers (UATs) are tapped off the isolated phase bus duct connecting the main generator to the GSU transformer. Each UAT is a three-phase, three-winding transformer, with a delta-connected 24.5 kV primary (input) winding, a wye-connected 13.8 kV output winding, and a delta-connected 4300V output winding. The 13.8 kV output winding of each UAT is connected to a switchgear bus. The 4300 V output winding is connected to one train of emergency switchgear and to non-essential switchgear. This line-up is shown in Attachment 4.

The two RATs provide an alternative off-site power supply to the on-site distribution system. The RATs, like the UATs, are three-phase, three-winding transformers. They supply the same busses as the UATs and are capable of powering all site loads including Busses E5 and E6. Each UAT and RAT has the capacity to supply the power requirements of the connected loads under all plant conditions.

Additionally, Seabrook Station has a generator circuit breaker which is provided between the main generator and the connections to the GSU transformer and UATs. The high voltage side of the GSU ties into the 345 kV switchyard ring bus. This position of the bus can be isolated from the remaining 345 kV switchyard by opening 345 kV Breakers 11 and 163.

345 kV System Operation

During unit start-up, the plant auxiliary loads are normally supplied from the 345 kV switchyard through the GSU to the UATs. In this case, the GSU functions as a step-down transformer and converts the 345 kV switchyard voltage to 25 kV for the UATs. When the unit generator output is adequate, the unit is synchronized with the 345 kV switchyard, the generator breaker is closed, and the unit is tied-in with the switchyard. Then the generator power flow is through the GSU to the switchyard and the unit supplies its own auxiliary power through the UATs. During normal operation, except for auxiliary power to the UATs, the output of the main generator flows to the New England transmission grid through the 345 KV switchyard distribution system.

During a normal shut-down, the unit load is reduced to approximately 50 MW and the generator breaker is tripped by tripping the main turbine. As the unit trips, the power flow through the GSU reverses to feed the UATs from the 345 kV switchyard.

4160 V System Operation

The 4160 V distribution system is comprised of four busses (3, 4, E5 & E6). Two 4160 V busses (E5 and E6), supply vital, safety-related loads and are considered part of the 'A' train and 'B' train load groups. The other two busses, 3 and 4, supply non-safety-related loads. Normally, the supply to the 4160 V busses is via the UATs. These transformers receive 25 KV power via the iso-phase bus from the unit's turbine-generator, or from the 345 kV switchyard distribution system via the generator step-up transformer (GSU). An alternate source of unit auxiliary power is the 345 KV distribution system via the RATs. This alternate source automatically supplies the various busses if the normal power supply is lost and the UAT output circuit breakers open. Another output winding on both the unit and reserve auxiliary transformers supplies power to the 13.8 KV distribution system.

In addition to a normal and alternate supply, Busses E5 and E6 have an emergency power supply in the form of the emergency diesel-generator associated with each train. A loss of all AC power to either of these busses starts the associated diesel-generator, which supplies power to the respective bus. The emergency power sequencer (EPS) coordinates the restarting of the loads on the bus to prevent overloading the diesel-generator.

The diesel-generator, UAT, and RAT supplies are connected to 4160 Busses E5 and E6 by individual circuit breakers. These breakers are electrically interlocked so that only one supply breaker per bus can be closed. The only time this interlock is bypassed is during controlled parallel operations of the diesel generators with the UAT or RAT supplies, (i.e., during recovery from a loss of all AC power, or during emergency diesel load runs).

The loads supplied by each bus in the 4160 V distribution system are isolated from the bus by individual circuit breakers, each mounted in a separate switchgear compartment. These breakers are electrically controlled, stored-energy-type breakers equipped with various combinations of overcurrent, differential-phase-current, or ground-fault-sensor (alarm only) relays.

The instrumentation associated with each bus monitors bus voltage, ground status, and the supply current from each power source. The components of the system are located in the Control Building, the Nonessential Switchgear Room, and the Site Transformer Yard.

Relay Protection and Breaker Controls

The 345 kV switchyard protective relay scheme consists of two similar systems. Both systems are separate and redundant. Each protective relay system provides phase overcurrent and ground protection for the 345 kV connecting busses, switchyard busses, and the associated 345 kV transmission lines.

Within the 345 kV switchyard, busses are protected by two sets of differential relays. These relays sense the current flow on and off the particular bus and operate only when those flows are unbalanced. In the event of a fault, these relays are designed to sense the unbalanced condition, and the relays trip and lock out the circuit breakers associated with the affected bus (including the main generator breaker). In addition, each breaker in the 345 kV switchyard is provided with a breaker failure relay (50BF) protective circuit. The breaker failure relay protective circuit isolates bus sections adjacent to a 345 kV circuit breaker that fails to trip open when called upon by the breaker failure relay protective circuit for the affected bus section.

In addition to the 345 kV circuit breaker failure relay protection circuit, the design had an out-of-step relaying protection scheme. Per discussion with the licensee, out-of-step relaying was provided to isolate the unit main generator during unstable grid conditions under "Northeast Power Coordinating Council, Bulk Power System Protection Criteria." The purpose of this out-of-step relay scheme was to watch the out-of-step condition (the phase angle between the generator voltage and the other units in the grid system). The associated generator current can surge cyclically as a function of the rate of slip of the generator's poles. These surges can vary from zero to twice the short-circuit current, which corresponds to the 180 degrees out-of-phase condition of the swing. If the out-of-step condition were prolonged, the bracing of the generator windings would be stressed and the windings would heat up. Also, the power system could be subjected to substantial surges.

Out-Of-Step Relay 78/B3 (GE Type SLL, Device 78) was designed and wired-in to the relay protection scheme. Current transformers (CTs) are shared by Breaker Failure Relays 50BF/21H & 50BF/21E for 345 kV Breakers 11 & 163 and by the generator Out-Of-Step Relay 78/B3.

The output signal of Out-Of-Step Relay 78/B3 provides an input to the two auxiliary relays, 86-78/B3 & 94-78/B3. Auxiliary Relay 86-78/B3 is a lockout GE Type HEA relay; Auxiliary Relay 94-78/B3 is a high speed Westinghouse Type AR relay. Both relays isolate the main generator from the 345 kV switchyard by tripping 345 kV Breakers 11 and 163. The design has no other trip function than out-of-step relay tripping.

Based upon review of the licensee maintenance procedures, and discussions, the breaker failure relays and generator out-of-step relay input circuits were placed in service by the licensee under Work Order 91W001290 on February 22, 1991, after plant power ascension testing.

7.2 Electrical System Response

The inspector reviewed the plant design documentation, the event evaluation, the maintenance test records, the alarm printout, and held discussions with plant engineering personnel. Generally, the plant electrical system responded as designed.

A manufacturing error in a non-safety-related relay housing contact block assembly of 345 kV switchyard Breaker Failure Relay 50 BF-2/H initiated the June 27, 1991 event. The contact block is designed to have a make-before-break feature which allows the relay to be removed from service and calibrated while other relay protection circuits remain in service. The contact assembly is typically comprised of a bank of "knife blade" switches in a relay housing. The knife blade switches are in pairs, with one of the paired switches being configured to make before break and the other being configured to break before make. This allows the device to be removed from a current transformer (CT) circuit without interrupting the circuit. In this case, one of the pairs was incorrectly assembled with two break-before-make switches. That assembly error was detected during post-trip troubleshooting.

The cause of the event was inadvertent tripping of Out-Of-Step Relay 78-B3 when Breaker Failure Relay 50BF-2H (345 kV BKR 11) was being restored. During the restoration, when the "C" phase current transformer (CT) contact was closed, an arc was noticed due to a momentary opening and closing of the CT secondary circuit. This resulted in a voltage spike being experienced in the protective circuit and resulted in tripping the out-of-step relay.

Consistent with the unit design (see Detail 7.1.), 345 kV Circuit Breakers 11 and 163 tripped and isolated the unit generator from the 345 kV switchyard. There was no transfer of offsite power to onsite busses from the Unit Auxiliary Transformers (UATs) to the Reserve Auxiliary Transformers (RATs) because the UAT output breakers do not trip on loss of input power. With the UAT output breakers shut, an interlock prevents closure of the RAT output breakers in order to avoid paralleling these sources. This feature was identified for further NRC evaluation.

7.3 Control of Procurement and Pre-Service Testing

The inspector reviewed the original specification, purchase order, and associated vendor drawings for the protective relays and control cabinets in the 345 kV Relay Room and found that this equipment was classified as non-class 1E equipment. This relay was procured as non-class 1E equipment as part of a relay panel. Since this equipment is not classified as safety related equipment, upon receipt, the licensees QA inspection could be and was waived. Review of the vendor's wiring diagrams revealed no further details of the knife blade switches. External wiring connection points were shown associated with other devices and terminal blocks.

This condition illustrates that the plant design incorporates components which are not safety-related but which are important to safety insofar as their malfunctioning can cause safety-significant transients such as reactor trips. Whether such components should be required to undergo receipt inspection and/or pre-service testing in all modes was identified for further NRC evaluation.

7.4 Assessment and Conclusion

Based on inspector review of the plant design basis, the licensee event evaluation and post-event testing evaluation, it was concluded that the plant electrical system responded as designed. 345 kV Breakers 11 and 163 tripped due to the momentary voltage spike introduced by a defective part of knife blade switches in the 50BF-2H relay cabinet. That led to a turbine trip.

Post-event testing and inspection adequately assured and confirmed the function of the affected devices in the event. In addition, caution tags were hung on the defective knife blade switch in conjunction with taking Out-Of-Step Relay 78/B3 out of the relay loop safeguard against recurrence of this event.

With the out-of-step relay isolated pending licensee resolution of this matter, the design was assessed as adequate. Additional inspector observations on the design follow.

- As evident in the NHY event report, when the out-of-step relay trips, a momentary high voltage transient is experienced in the station auxiliary system due to the redistribution of generator output power.
- The present design relies on another station component to isolate (trip) the output breakers of the unit auxiliary transformers from their respective busses.
- By initiating an EDG start signal from out-of-step relay actuation, the EDG could be started approximately two seconds earlier when transfer to the RATs is not appropriate.

8.0 QUALITY ASSURANCE/SAFETY VERIFICATION

The inspector reviewed drafts of the licensee event evaluation, attended the meeting where that event evaluation was presented to management, and held discussions with station management.

The NHY Event Evaluation Team presented a detailed description of the event, operator actions, and equipment response to station management on June 28, 1991. The cause of the event and actions requiring completion prior to restarting the reactor were identified. Equipment and operations problems were reviewed and recommendations for follow-up actions were made.

The 78/B3 relay was tagged out of service and the 50BF-2/H relay was left in service with a caution tag prohibiting any maintenance. These actions were completed prior to reactor start-up. During the first refueling outage, beginning July 27, 1991, all relay assemblies similar in design to 50BF-2/H relay were scheduled to be inspected for correct knife switch assemblies, with any defective casings to be replaced. A long term review and evaluation of the tripping scheme for the 78/B3 relay was initiated.

Other evaluations were initiated as a result of equipment operational problems identified during the recovery of the plant. SG-C Safety Valve MS-V 38 was scheduled to be disassembled and inspected during the first refueling. The design of the fire alarm system in the pipe chases and potential interim enhancements to fire response procedural guidance were planned to be evaluated.

Several enhancements to procedures were planned to be evaluated based on plant performance observed during the event. A requirement for closing the MSIVs to protect the main condenser was planned to be evaluated. Additional detailed guidance is to be added to Procedure OS-1242.01, "Loss of Instrument Air," to identify the instrument air header pressures necessary to operate ASDVs in MODULATE and to open the cross-connect valves to the service air header.

The inspector concluded that the NHY Event Evaluation Team conducted a thorough review of the event, identified the cause, and recommended acceptable corrective actions. Station management properly challenged the conclusions of the Event Evaluation Team and assessed the adequacy of short-term and long-term corrective actions. The Event Evaluation Team continued their evaluation after the June 28 presentation to more fully develop and define long-term corrective actions.

The inspector concluded that an excellent self-evaluation of the event was conducted and that further evaluations and system designs reviews, especially in the area of protective relaying, remain to be completed.

ATTACHMENT 1

SEQUENCE OF EVENTS

Time	Event
1300	The 69/86BF-2111 permissive switch was tagged out to prevent tripping the plant. Work was authorized to begin.
1305	NEPSCO personnel removed the Breaker Failure Relay 50BF-2/11(H) relay from service by opening knife switches. A small spark was thought to have occurred.
1334:44	NEPSCO personnel reinstalled Breaker Failure Relay 50BF-2/11(H) and closed the knife switches. A large spark was noted.
1334:44	• 345 kV Breakers 11 and 163 opened, isolating the Main Generator and the Unit Auxiliary Transformers (UATs) from the switchyard. • All site busses deenergized, removing power from the Reactor Coolant Pumps (RCPs). • No auto transfer from the UATs to the Reserve Auxiliary Transformers (RATs) occurred. • Turbine trip. • Reactor trip.
1334:45	Inverter 1E momentarily deenergized, causing Control Building Air (CBA) and Containment Ventilation Isolation (CVI) Train "A" ESF to actuate. No physical CBA or CVI changes resulted.
1334:46	Undervoltage alarm on Busses E5 and E6.
1334:55	Vital Busses E5 and E6 were energized from the Emergency Diesel-Generators (EDGs 1A and 1B). Reactor Trip Emergency Operating Procedure (EOP) E-O was entered. Transition was made to Reactor Trip Response EOP ES-0.1. The NRC Operations Center was informed of the reactor trip and loss of power.
1335	Steam Generator (SG) Atmospheric Steam Dump valves (ASDVs) opened to limit main steam line pressure.
1336	Diesel-driven Fire Pump FP-P-20A started on low fire header pressure due to loss of power to the motor-driven fire pump being used to flush the fire header.

1338	Valves SA-V92 & 93 {which isolate the Instrument Air (IA) and Service Air (SA) headers from each other} closed when IA header pressure decreased below 70 psig.
1342	Motor-driven Emergency Feedwater (EFW) pump was started. Turbine-driven EFW pump was secured.
1345	NRC Operations Center called NRC resident via the Emergency Notification System.
1348	Establishment of natural circulation of primary plant was verified.
1349	The Main Steam Isolation Valves (MSIVs) were manually closed.
1350	Radiation alarm on waste gas compressor discharge.
1350	NHY reported event to Seabrook police.
1352	Service Air Compressors A & B were started. IA header pressure was 27 psig.
1353	RAT placed in service.
1355	Radiation alarm on waste gas compressor discharge cleared.
1356	SA-V91 and 92 were opened with nitrogen. IA header pressure decreased from 48 psig to 43 psig.
1400	Condenser vacuum was broken.
1402	Reactor Coolant Pump RCP-C was started. SG-C alarms on level and steam flow due to pressure transients. One SG-C safety valve lifted.
1403	Fire Alarm in East Pipe Chase. ASDV "C" was placed in "Position Maintain." Fire fighters dispatched.
1405	Radiation alarm on condenser air release monitor.
1407	Control Room Operator (CRO) notified of open safety-relief valve. CRO opened ASDV-C using nitrogen backup.
1415	Vital Bus E5 was energized from off-site power.

1420	Vital Bus E6 was energized from off-site power.
1425	Exited ES-O1. Entered OS-1000.11.
1427	Stopped EDG-1A.
1430	Stopped EDG-1B.
1434	IA header pressure 80 psig.
1444	135 kV Breakers 11 and 163 were closed.
1445	NRC Operations Center call to NRC resident was terminated.
1534	NHY reported event to NRC Operations Center per 10 CFR 50.72(b).2.ii (four-hour report).

ATTACHMENT 2

PARTIAL LISTING OF TELEPHONE COMMUNICATIONS
FOLLOWING ELECTRICAL TRANSIENT

Approximate Time After Trip @ 1:34 p.m.	To	From	Topic
0	Control Room	NRC Ops Center, Washington, DC	Ops Center informed of plant trip - responding to transient
1 Minute	Site Personnel	Control Room	Public address announcement of reactor trip
5-10 Minutes	Plant Manager	Operations Manager	Initial plant status update
5-10 Minutes	Senior Management	Plant Manager	Plant status update, agreed senior management would notify corporate communications
10-12 Minutes	NHY Corporate Communications	Senior Management	Informed of plant status
Various Times	Internal NHY	Corporate Communications	Switchboard, Science and Nature Center, Community Relations Department, Government Affairs, etc. informed of plant status
	NH PUC Onsite Representative	Corporate Communications	Informed of plant status (call in progress before trip)
16 Minutes	Seabrook Police/Fire	Corporate Communications	Informed of plant status

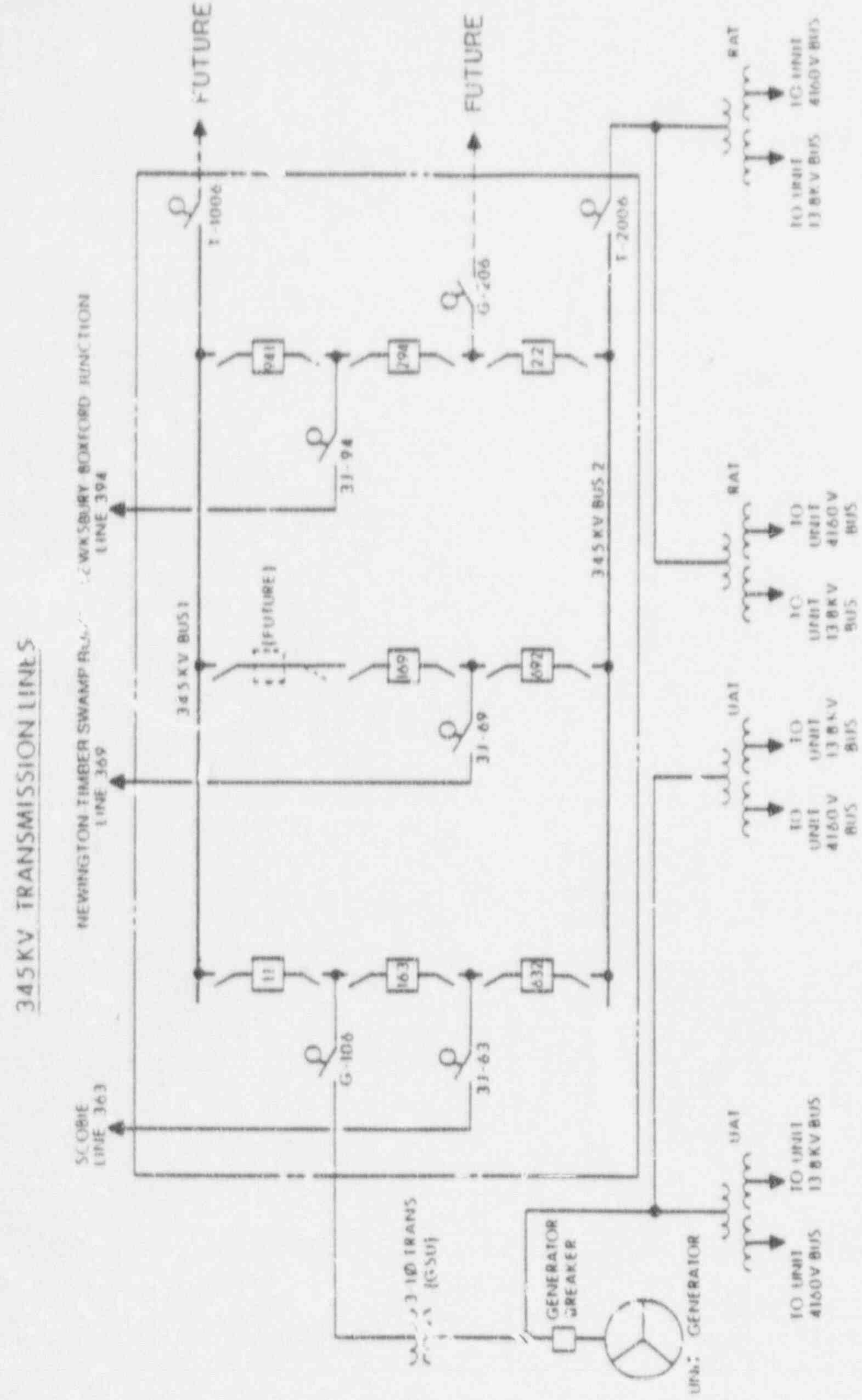
Approximate Time After Trip @ 1:34 p.m.	To	From	Topic
23 Minutes	Hampton Police	Corporate Communications	Informed of plant trip (Hampton Falls area included)
25 Minutes	Salisbury Police	Corporate Communications	Informed of plant trip
41 Minutes	Community Call-In	Corporate Communications	Taped message updated for trip, (603) 433-0440
46 Minutes	Corporate Communications	Local Newspaper	Reporter calls for plant status based on report from local resident
51 Minutes	Associated Press International	Corporate Communications	Verbal briefing, RE: plant trip
61 Minutes	Hampton Fire	Corporate Communications	Informed of plant trip
63 Minutes	Rockingham County	Corporate Communications	Informed of plant trip
64 Minutes	Corporate Communications	NRC, Region I	Public Affairs Officer checked plant status
66 Minutes	NH Office of Emergency Management	Corporate Communications	Communications counterpart informed of plant trip (NRC had contacted NH through a different person about this time)
66 Minutes	United Press International	Corporate Communications	Verbal briefing, RE: plant trip

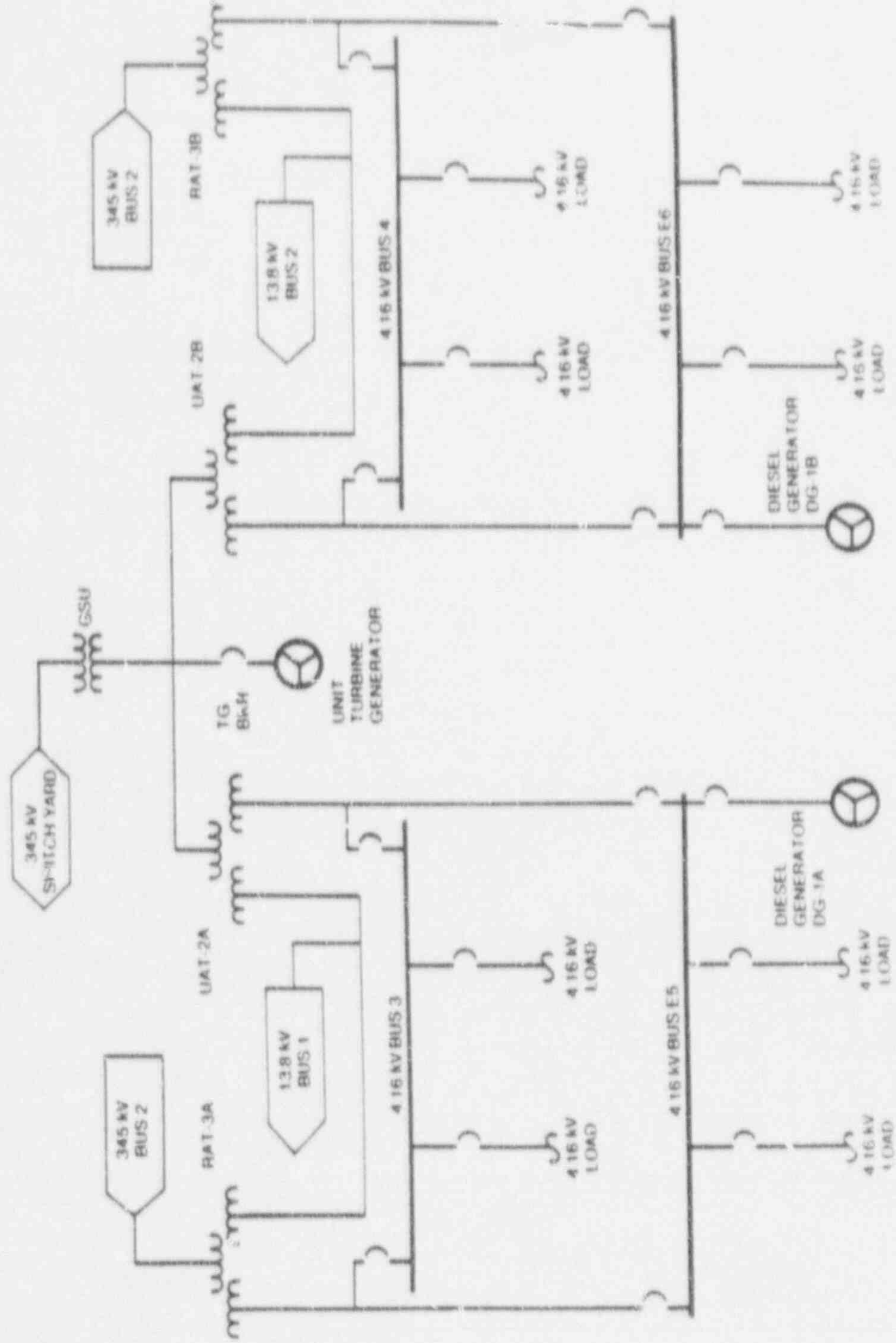
Approximate Time After Trip @ 1:34 p.m.	To	From	Topic
86 Minutes	NHY Corporate Office	Massachusetts Civil Defense Agency	Had been notified by NRC at ~14:50; desired status report and details of classification

This table does not include the additional calls made to Emergency Management Directors or town officials in the ten mile radius of the plant.

345 kV ONE-LINE DIAGRAM

ATTACHMENT 3




345 kV BUS 2
RAT-3B
13.8 kV BUS 2
UAT-2B
4.16 kV BUS 4
4.16 kV BUS E6
4.16 kV LOAD
4.16 kV LOAD
4.16 kV LOAD
4.16 kV LOAD
DIESEL GENERATOR DG-1B
GSU
345 kV SWITCH YARD
TG BKR
UNIT TURBINE GENERATOR
UAT-2A
13.8 kV BUS 1
RAT-3A
345 kV BUS 2
4.16 kV BUS 3
4.16 kV BUS E5
DIESEL GENERATOR DG-1A
4.16 kV LOAD
4.16 kV LOAD
4.16 kV LOAD
4.16 kV LOAD