CHAPTER 8 – ELECTRICAL SYSTEMS

TABLE OF CONTENTS

CHAPTER 8 – ELECTRICAL SYSTEMS

LIST OF TABLES

CHAPTER 8 – ELECTRICAL SYSTEMS

LIST OF FIGURES

8.0 ELECTRICAL SYSTEMS

8.1 DESIGN BASES

The design of the electrical systems for the Three Mile Island Nuclear Station Unit 1 is in compliance with the requirements of proposed AEC Criteria 24 “Emergency Power for Protection Systems,” and 39 “Emergency Power for Engineered Safety Features,” of July 11, 1967 (Reference 7) and provides required power sources and equipment to ensure continued operation of essential reactor and station auxiliary equipment under all conditions. The design satisfies the Institute of Electrical and Electronics Engineers (IEEE) Report No. NSG/TCS/SC4-1, "Proposed IEEE Criteria for Class 1E Electrical Systems for Nuclear Power Generating Stations," dated June 1969 (see Section 8.6, Reference 4). [The Atomic Energy Commission evaluated the electrical power system for Three Mile Island Unit 1 against General Design Criteria 17 (Reference 18) “Electrical Power Systems” and 18 “Inspection and Testing of Electrical Power Systems” of July 1971.]

The capacity and capability of the offsite power system and the onsite distribution system with the clarifications described in Section 8.2.1.2.f. is adequate to automatically start as well as operate all required safety loads within their required voltage ratings in the event of an anticipated transient, or an accident without manual shedding of any electric loads. On the basis of the very low probability of occurrence of a degraded grid condition, single auxiliary transformer operation and design basis LOCA, it is concluded that only low probability events or conditions could result in the simultaneous, or consequential loss of both required circuits from the offsite network to the onsite electric distribution system. A degraded grid condition is defined as a voltage level experienced on the 230kV system that would result in a system voltage that is below the Post-Contingency voltage (Reference 23). If the post contingency voltage is less than the value required to support safety related ES loads, the transmission system operator will notify the TMI Unit 1 control room. The control room enters the appropriate Technical Specification action statements.

General Design Criterion (GDC) 17 (Reference 18) specifically requires that a reliable source of offsite power be provided to the plant. The licensee and Metropolitan Edison Company have entered into an Interconnection Agreement, whereby Metropolitan Edison Company provides the TMI-1 site with interconnection services, including arrangement for controlling operation, maintenance, repair, and other activities with respect to the TMI-1 substation relay house, the transmission lines, and the switchyard. Further, the licensee maintains a separate Transmission and Power Services Agreement with other provider(s) for transmission and power services to the TMI-1 site. The obligations of Metropolitan Edison Company under the Interconnection Agreement, and those of the transmission and power services provider(s) under its agreement with the licensee provides assurance that the GDC 17 criteria for a reliable source of offsite power continue to be met.

8.2 ELECTRICAL SYSTEM DESIGN

8.2.1 NETWORK INTERCONNECTIONS

Unit 1 generates electric power at 19 kV, which is fed through an isolated phase bus to the unit main transformer bank, where it is stepped up to 230 kV transmission voltage and delivered to the substation. The substation design incorporates a breaker-and-a-half scheme for high reliability and is connected to the existing Metropolitan Edison Company 230 kV transmission network by four circuits, two full capacity circuits going north to Middletown Junction on separate double circuit towers, one half capacity circuit going southwest to Jackson on single circuit towers, except the first 4 towers are shared with the 230kV/500kV auto transformer connection, and one line to a 230 kV/500 kV autotransformer connection to the Metropolitan Edison Company 500 kV grid. Middletown Junction, located 1.5 miles from Three Mile Island, is a major substation in the Pennsylvania New Jersey Maryland Interconnection with 230 kV transmission line connections north to Hummelstown, east to South Reading, and south to Brunner Island, a 1500 MW generating station owned and operated by the Pennsylvania Power & Light Company.

Site transmission lines are routed as shown on Drawing E-229-001 and E-229-002.

8.2.1.1 Single Line Diagram

Drawings E-229-001 and E-229-002, present a single line diagram of the substation electrical system.

8.2.1.2 Reliability Considerations

Reliability considerations to minimize the probability of power failure due to faults in the network interconnections and the associated switching are as follows:

a. The two Middletown Junction circuits are each capable of carrying full unit output and are located on different double circuit towers. The Middletown Junction lines are separated from the Jackson Line (see Item b below) on the Three Mile Island site by a distance greater than the height of the tower.

b. The line to Jackson is capable of carrying 50 percent of full unit output and follows an entirely different route than the lines to Middletown Junction.

c. The Middletown Junction substation is only 1.5 miles away, thus reducing line exposure.

d. The breaker-and-a-half switching arrangement in the 230 kV substation includes two full capacity main buses. Primary and backup relaying has been provided for each circuit along with circuit breaker failure backup switching. These provisions permit the following:

    1) Any circuit can be switched under normal or fault switching without loss of external power sources.

2) Any single circuit breaker can be isolated for maintenance without interrupting the power or protection to any circuit.

3) Short circuit of a single main bus will result in the loss of one auxiliary transformer but will be isolated without interrupting service to any outgoing line (also refer to Section 8.2.2.2).

4) Short circuit failure of the tie breaker will result in the loss of its two adjacent circuits until it is isolated by disconnect switches.

5) Short circuit failure of a bus side breaker will result in the loss of one circuit and one auxiliary transformer until it is isolated.

6) Circuit protection will be ensured from failure of the primary protective relaying by backup relaying.

e. The bulk transmission system has been examined for performance during system disturbances; using normal case load flows, transient stability studies, and post-transient load flow studies. It has been determined that the system performs adequately for the predicted worst case single contingency (one line or other failure) on the bulk transmission system with normal system adjustments, followed by the loss of the TMI-1 generator. For these conditions, there was no loss of load in the system, the TMI-1 230kV substation is not interrupted, and a predicted minimum grid (substation) voltage is determined. Once per year any changes made to the transmission system that would affect voltage stability at TMI-1 are reviewed and if necessary, a new value for the minimum expected/predicted grid voltage is obtained.

f. Analytical studies are completed to ensure that the offsite power system of TMI-1 with two auxiliary transformers is of sufficient capacity and capability to provide power to automatically start as well as operate all required safety loads at the minimum expected/predicted grid voltage. (Reference 6 & 23)

For single transformer operation these analytical studies assume the offsite power system is in the system operating range and above the post contingency voltage (reference 23) with one ES bus powered by its diesel generator.

The TMI-1 Plant Electrical Distribution system design will adequately protect the safety related electric equipment from loss of capability of redundant safety loads, their control circuitry and associated electrical components required for performing safety functions as a result of sustained degraded voltage from the offsite electric grid system.

Loss of voltage protection on the 4160 V safety buses is provided by three solid state instantaneous relays on each bus arranged in a two-out-of-three coincident logic scheme with a voltage setpoint 58 percent of nominal bus voltage and a time delay of 1.5 seconds. These relays will trip the safety bus feeder breaker, initiate load shedding, start the respective diesel generator and sound an annunciator in the main Control Room.

Degraded grid voltage protection on the 4160 V safety buses is provided by three additional relays on each bus arranged in a two-out-of-three coincident logic with a voltage setpoint 90.4 percent of nominal bus voltage, and a time delay of 10 seconds. These relays will trip the associated safety bus feeder breaker, initiate load shedding, start the diesel generator and sound an annunciator in the main Control Room. This second level undervoltage protection setpoint provides the necessary protection for the 480 volt safety related electrical loads for the worst case electrical lineup and loading assuming a degraded grid condition, maximum BOP loading, and design basis LOCA loads with reactor trip.

If only one (1) auxiliary transformer is operation, one ES bus will normally will be on the diesel generator and the rest of the loads will be on that auxiliary transformer. A separation from the grid will not occur in this line-up when the LOCA block loads are added if the 230kV system remains above the post contingency voltage. If voltage falls below the post-contingency voltage, a 24-hour Technical Specification LCO is entered.

Additional undervoltage protection is provided by relays on the 480 V safety buses. These relays annunciate in the Control Room at approximately 92 percent of the nominal rating of the motors (460V) connected to these buses to alert the operators to a low voltage condition to allow time to shed unnecessary loads to restore voltage and preclude trips, if possible.

The 230 kV voltage is monitored on the TMI-1 plant computer which initiates a high and low alarm in the Control Room. Operator guidance recommends that the operator notify PJM when the low alarm is received and the unit is operating in the single auxiliary transformer configuration. A high alarm will notify the PJM operators when the 230 kV bus reaches the high grid voltage alarm. The PJM system operator will take action to reduce the 230 kV bus voltage.

The system is also designed to provide the required protection without causing voltages to exceed the voltage ratings of the safety loads and without causing spurious separations of the safety buses from offsite power.

With the above protective features, the probability of loss of more than one source of 230 kV power from faults is low; however, in the event of an occurrence causing loss of up to all the 230 kV remote connections, the engineered safeguards will be supplied from one or more of the remaining sources of power (refer to Section 8.2.3).

8.2.2 UNIT DISTRIBUTION SYSTEM

The Unit 1 distribution system consists of the various auxiliary electrical systems designed to provide reliable electrical power during all modes of operation and shutdown conditions. The systems have been designed with sufficient power sources, redundant buses, and required switching to accomplish this. Engineered safeguards auxiliaries are arranged so that loss of an emergency diesel generator or of a single safeguards bus for any reason will still leave sufficient auxiliaries to safely perform the required functions. In general, each of the auxiliaries related to functions other than engineered safeguards is powered from one of the three 4160 V unit auxiliary buses. Engineered safeguards loads have been divided between the two Class 1E auxiliary power systems in observance of the single failure criterion.

8.2.2.1 Single Line Diagram

Drawing E-206-011 is a single line diagram of the Unit 1 distribution system.

8.2.2.2 Auxiliary Transformers

Two “full-size” auxiliary transformers are connected to different 230 kV buses and provide a source of power for startup, operations, shutdown, and after shutdown requirements. Each transformer has the MVA capacity to handle all of the above loads. Each transformer has a Load Tap Changer (LTC) installed on the 4kV winding that senses voltage at its respective ES bus to control voltage within a narrow band with grid voltage variations. The LTC control consists of two control devices, a primary controller and a backup controller. The primary controller indicates the raise and lower signals required to maintain voltage within a narrow band. The back-up controller provides blocks to limit the magnitude of an undervoltage or overvoltage event as a result of a LTC control failure. Manual control of the LTC is also provided locally at the transformer control panel and in the control room on panel ‘PR’. Actuation of the LTC and LTC controls will be performed at a regular interval to ensure proper operation and to detect any failures.

During single transformer operation separation from the grid will not occur with LOCA loading if the post trip grid voltage is predicted to remain above the single transformer post contingency voltage. If post trip grid voltage is predicted to fall below the single transformer post-contingency voltage and LOCA loads were to be added then a separation of ES bus from the transformer may occur. The ES loads will then be automatically placed on the emergency diesel generators. Either of the two transformers will also serve as a standby source in the event of one auxiliary transformer failure, with a further source as noted in Subsections 8.2.3.1.b and 8.5.2.

Technical Specification Section 3.7.2.b restricts single auxiliary transformer operation to a period of 30 days, during which both emergency diesel generators (EDG) must be operable with one EDG running continuously within 8 hours after the loss of one auxiliary transformer. Technical Specification 3.7.2.h restricts operation to 24 hours if it is determined that a trip of TMI-1 in conjunction with LOCA loading will result in a loss of offsite power to ES buses. This ensures a continuously available power supply for the engineered safeguards equipment. Each of the aforementioned transformers has two isolated secondary windings, one at 6900 V and one at 4160 V, for the purposes outlined in the following subsections.

8.2.2.3 6900 V Auxiliary System

The 6900 V auxiliary system is designed solely for the 9000 hp reactor coolant pump motors. This system is arranged into two bus sections, each feeding two motors. During normal operation one bus is fed from each auxiliary transformer, although either transformer is capable of feeding both buses. Automatic transfer will take place in either direction, by relay action, if a source bus or transformer failure occurs. Normal bus transfers initiated at the discretion of the operator for test or maintenance purposes will be "live bus" transfers, i.e., the incoming source feeder circuit breaker will be closed onto the running bus section and the outgoing source feeder circuit breaker will be tripped, which will result in transfers without power interruption. Manual paralleling of sources which are out of phase is prevented by the use of synchronism check relays.

Emergency transfers which result upon loss of normal unit sources will be rapid bus transfers, i.e., the outgoing source feeder circuit breaker will be tripped and its interlocks will permit the incoming source feeder circuit breaker to close. This will result in a transfer within six cycles.

8.2.2.4 4160 V Auxiliary System A single line diagram is given on Drawing E-206-022.

The 4160 V auxiliary system has five bus sections. Buses 1A, 1B, and 1C are provided for balance of plant (BOP) functions. Turbine generator and other non-safety related loads have been divided among these buses for increased plant reliability.

Buses 1D and 1E are the 4160 V buses of the two redundant Class 1E electrical systems whose preferred power sources are from different 230 kV substation buses through two auxiliary transformers. There will be no fast automatic transfers of the Class 1E buses. Transfers of either bus to the alternate preferred source will be manual. Operation with both ES buses on a single auxiliary transformer will be administratively limited. Transfers to the emergency diesel generator sources will be manual if bus voltage has not failed and automatic if bus voltage fails. A 2 out of 3 logic is used to prevent false action due to voltage relay failure. Automatic closure of diesel generator breakers is supervised by auxiliary contacts of other bus feeder breakers to ensure that all other sources have been cleared by the voltage relays and the associated bus is dead. No common failure mode exists for this system.

Load Tap Changers (LTC) are provided on the 4kV windings to maintain ES voltages within a narrow band for variations in grid voltage. Each LTC is controlled by a primary controller that senses voltage at the 4kV ES bus through a potential transformer on the line side of the normal feeder breaker. Auxiliary transformer 1A senses voltage on the line side of the feeder breaker at the 1E ES bus and transformer 1B senses voltage on the line side of the feeder breaker at the 1D ES bus. The primary controller settings are designed to maintain 4kV ES voltage between 4162 to 4218 volts. Computer alarms alert operators to voltage conditions outside this normal band. The back-up controller provides blocks to limit the magnitude of an undervoltage or overvoltage event as a result of a LTC control failure. The undervoltage block or lower block actuates at 4095 volts and will prevent a loss of offsite power to the applicable ES bus under normal voltage and loading conditions. The overvoltage or raise block is generated at two levels. The first level (HI) actuates at 4305 volts, which prevents 480-volt equipment from being exposed to a degrading overvoltage condition. The second level (HI-HI) actuates at 4340 volts, which exposes 480-volt equipment to a voltage slightly above ratings. The HI-HI block is designed to mitigate an inadvertent raise signal as a result of a contact or limit switch failure in the raise control circuit. The HI-HI block isolates all raise signals and allows the voltage to be reduced to within equipment ratings.

8.2.2.5 480 V Auxiliary System

The 480 V auxiliary system, exclusive of BOP heating and ventilating buses, has ten single-ended power centers, each consisting of a 4160/480 V transformer and its associated 480 V switchgear. Seven similar power centers have been provided for plant heating and ventilating.

Power centers 1P and 1R and power centers 1S and 1T comprise the 480 V switchgear of the two redundant Class 1E electrical systems. Since these power centers will be fed from appropriate 4160 V safeguards buses in accordance with the proposed standards noted in Section 8.1, transfer of power sources is inherent with transfer of 4160 V buses 1D and 1E as discussed in Section 8.2.2.4. Selected loads connected to 480 V power centers 1P and 1S are automatically tripped on receipt of an engineered safeguards signal. No common failure mode exists for this system. A single line diagram of the 480 V buses 1P, 1R, 1S, and 1T is given on Drawing E-206-032. Motor control centers feeding engineered safeguards equipment have been arranged so that engineered safeguards channels, power systems, and redundant equipment are fed and controlled with no cross connections of any kind. All pump motors, valve motors, switchgear and control centers, cable tray, conduit, and Reactor Building penetrations have been color coded wherever safeguards or reactor protection features are involved. Cross connections between, or routing through, items of unlike color are not permitted. No common failure mode exists for this system.

Drawings B-201043, B-201052, B-201069, B-201044, B-201053, B-201062 and B-201063 list the electrical loads connected to the Engineered Safeguards 480 V Control Centers.

8.2.2.6 250/125 Vdc System

The 250/125 Vdc system provides a source of reliable continuous power for DC pump motors, control, and instrumentation. In general, DC motors are rated 240 Vdc and control circuits 125 Vdc.

The 250/125 Vdc system consists of two isolated bus sections, each supplied by a battery and battery chargers. A spare 125 Vdc battery charger is provided for each battery for backup.

The arrangement and number of batteries, chargers, and dc distribution panel boards are as shown on Drawing E-206-051. The output of spare battery chargers may be fed to either half of the corresponding 250/125 Vdc system, and provision has been made for manual cross-connection of the two systems during battery discharge tests. By this means, all battery chargers would be available for feeding the essential loads. The manually operated bus tie is protected on both ends by normally locked open fused switches. The fuses are removed and the switches are locked open on the DC tie in the 230 kV substation.

Each battery charger has its own input and output protective circuit breakers. Each battery charger is connected to its associated distribution bus through fused disconnect switches. The battery chargers utilize silicon controlled rectifiers (SCRs) and, thus, are inherently protected against becoming a load on the DC bus during AC power outages.

As shown on Drawing E-206-051, under plant operating conditions there are no DC ties between redundant engineered safeguards equipment, switchgear, motors, and so forth, and, therefore, no single failure of any DC component can adversely affect the operation of the 100 percent redundant diesel generators. The entire system satisfies the IEEE criteria given in Reference 4, Section 8.6.

The capacity of each of the two redundant batteries is sufficient to feed its connected essential load for 2 hours continuously and perform three complete cycles of safeguard breaker closures and subsequent tripping. The 2 hour rating is based on the time required to ensure that all nuclear and BOP emergency equipment can perform its intended function and on the criteria contained in Draft 3 of Reference 4, the IEEE criteria for Class 1E electrical systems.

Each battery has been sized to have no less than the ratings given below, based on the use of 116 cell batteries and discharge to 1.81 Vdc per cell, at 77F 210/105 Vdc across the battery:

Reserve time	Discharge Rate AMPS	AMP-Hour Capacity
8 Hours	177.5	1420
3 Hours	370	1110
2 Hours	475	950
1 Hour	665	665
1 Minutes	1160	-

Each battery charger has been sized at 150 amperes continuous rating. This would allow a battery to be fully recharged in less than 16 hours, with the normal load of the battery system being carried simultaneously. For design basis loadings on each of the Station Battery systems A and B refer to Calculation C-1101-734-5350-003 (Reference 25).

Batteries are sized in accordance with IEEE-485-1983 method, and load profile is determined for each battery. The sizing includes an ambient temperature correction and an aging factor. Because of space limitations in the battery rooms, the "A" battery is slightly undersized. The size limits the usable life of the battery. The acceptance criteria in the Station Battery Load surveillance is specified so that the battery will have the required capacity and temperature margin at the end of the surveillance interval.

The following alarms are provided in the Main Control Room for the DC power supply system:

Alarm	Actuated By
Battery 1A Ground	Station battery 1A ground detector
Battery 1B Ground	Station battery 1B ground detector

Alarm	Activated By
1A Battery Charger System Trouble	1A battery chargers power failure 1A battery chargers DC volts low/high
1B Battery Charger System Trouble	1B battery chargers power failure 1B battery chargers DC volts low/high
Battery Discharging	Either battery current high or battery voltage low on either battery section

Substation Panels DC-A and DC-B have been provided with a backup DC power supply. The batteries are rated 200 ampere hours and are located in the 230 kV switchyard. In the unlikely event of loss of station DC supply, power to the substation panels DC-A and DC-B can be turned on manually from the Substation Battery.

A single line diagram of the DC system showing essential loads is given on Drawing E-206-051.

8.2.2.7 120 V Vital Power System

The 120 V vital power system provides a reliable source for essential power, instrumentation, and control loads. The system consists of four bus sections, VBA, VBB, VBC, and VBD, each supplied from a static inverter. Tie circuits are provided to the 120 V regulated power system described in Section 8.2.2.8 for backup power. The static inverters are supplied normally from the 480 V system through rectifiers with an uninterrupted transfer to a 125 V Capacity DC source, (i.e., battery or battery and battery charger) on loss of the normal supply.

A fifth inverter, inverter 1E, is provided and, by means of a manual Kirk Key interlock system, it can be connected to either the A or C 120 V vital buses to provide qualified backup power and to facilitate servicing the inverters.

A sixth inverter, inverter 1F, is provided and, by means of a manual Kirk Key interlock system, it can be connected to either the B or D 120 V vital buses to provide qualified backup power and to facilitate servicing the inverters.

The Vital Buses are not operable when powered from 120 V regulated panel TRA or TRB since the regulating transformers for TRA and TRB are not safety related or seismically qualified.

The time that each vital bus can be out of service is established by the Limiting Condition for Operation of the Tech Spec components that require power to perform their Technical Specification function. The allowed outage time applies during plant conditions when the component is required to be operable.

A static switch with automatic synchronizing capability is provided with the 1A and 1E inverters and is utilized to feed the Integrated Control System (ICS) and Non-Nuclear Instrumentation (NNI) and other loads. Static switch 1A will automatically transfer its ICS/NNI loads from the Distribution Panel VBA to the regulated AC bus, Distribution Panel TRA, with no interruption of power in the event that there is a failure of the inverter 1A. Static switch 1E will automatically transfer its ICS/NNI loads to TRB with no interruption of power in the event of a failure of inverter 1E.

The following alarms are annunciated in the Control Room for the 120 VAC vital power system:

Alarm	Actuated By
1A/1C/1E Inverter Trouble	Inverter 1A DC volts low Inverter 1A DC volts high Inverter 1A battery overcurrent Inverter 1A frequency high/low Inverter 1C DC volts low Inverter 1C DC volts high Inverter 1C battery overcurrent Inverter 1C frequency high/low Inverter 1E DC volts low Inverter 1E DC volts high Inverter 1E battery overcurrent Inverter 1E frequency high/low

1B/1D/1F Inverter Trouble	Inverter 1B DC volts low Inverter 1B DC volts high Inverter 1B battery overcurrent Inverter 1B frequency high/low Inverter 1D DC volts low Inverter 1D DC volts high Inverter 1D battery overcurrent Inverter 1D frequency high/low Inverter 1 F DC volts low Inverter 1 F DC volts high Inverter 1 F battery overcurrent Inverter 1 F frequency high/low
Inverter on Batt 1A	Inverter 1A on station battery Inverter 1C on station battery Inverter 1E on station battery
Inverter on Batt 1B	Inverter 1B on station battery Inverter 1D on station battery Inverter 1 F on station battery
Inverter Failure	Inverter 1A output volts low Inverter 1B output volts low Inverter 1C output volts low Inverter 1D output volts low Inverter 1E output volts low Inverter 1 F output volts low

The entire 120 V vital power system satisfies the IEEE criteria for Class 1E Electrical Systems (see Section 8.6, Reference 4) as well as applicable provisions of IEEE Standard 279 (Reference 14) (See 7.5, Reference 2) for nuclear power plant protection systems. This system is shown on Drawing E-206-051. No common failure mode exists for this system.

8.2.2.8 120 V Regulated Power System

A 120 V regulated power system supplies instrumentation, control, and power loads requiring regulated 120 V power. It consists of distribution panels and regulating transformers fed from motor control centers and is shown on Drawing E-206-051.

This Regulated Power System provides a non-qualified backup power source to the 120 V Vital Buses. See Section 8.2.2.7.

8.2.2.9 120-Y-208 V Power System

A low voltage 120-Y-208 V power system supplies instrumentation, control, and power loads requiring unregulated 120-Y-208 V power. It consists of distribution panels and transformers fed from motor control centers.

8.2.2.10 Evaluation Of The Physical Layout, Electrical Distribution System Equipment

The electrical distribution system equipment has been located so as to minimize the vulnerability of vital circuits to physical damage. The locations are as follows:

a. The two full sized auxiliary transformers are located outdoors, physically separated from each other. Lightning arresters have been provided on the high voltage winding for lightning protection. The transformers are protected by automatic water spray systems to extinguish oil fires quickly and prevent the spread of fire. Transformers are separated by walls to minimize their exposure to fire, water, and mechanical damage.

b. The unit auxiliary 6900 V switchgear, 4160 V switchgear, and 480 V switchgear are located in areas so as to minimize exposure to mechanical, fire, and water damage. This equipment is coordinated electrically.

c. Engineered safeguards 4160 V switchgear and 480 V power centers are located in seismic Class I areas within structures designed for the hypothetical aircraft incident. Separation of redundant power systems has been maintained throughout. This equipment is coordinated electrically.

d. The 480 V unit substations are free standing power centers with a high voltage section, a 1000/1333 kVA dry type transformer and 480 V low voltage switchgear sections in each. The dry type power transformers are provided with fans for forced cooling. All of these components, with the exception of the dry type transformers are rated for continuous operation at a maximum ambient air temperature of 104°F.

   The 480 V unit substation transformers are rated at 1000/1333 kVA at an average ambient temperature of 86°F, provided that the maximum ambient temperature does not exceed 104°F. During normal plant operation the maximum ambient room temperature in the 1P and 1S Switchgear rooms may go up to 95°F. Under normal plant operating conditions, with both the 1P and 1S unit substations available, the transformers are loaded to approximately 50-60 percent of their capacity. The 1P and 1S unit substations are redundant safety related systems required for safe shutdown. During a degraded voltage condition with only one of these transformers available (worst case loading), one of the two transformers may be loaded up to its rated capacity. Under this condition the ambient room temperature may approach 104°F due to the increased heat input to the room from the transformers. At a 104°F room temperature, the transformers must be derated to 1253 kVA (94 percent of nameplate rating of 1333 kVA). Expected loading on either transformer during this condition is less than the derated capacity at 104°F.

   Intake Screen and Pumphouse Unit Substations 1R and 1T are derated to 1173 kVA in order to accommodate a change in allowable ambient from 104°F to 120°F.

e. 480 V motor control centers are located in the areas of electrical load concentration. Those associated with the turbine generator auxiliary systems in general are located below the turbine generator operating floor level. Engineered safeguards motor control centers are located in seismic Class I areas within structures designed for the hypothetical aircraft incident. Separation of redundant power systems has been maintained throughout.

f. The station batteries and associated chargers and inverters are in separate rooms within the Control Building, which is a Class I structure designed to withstand the hypothetical aircraft incident, to minimize vulnerability to damage. Station batteries A and C are in one room; station batteries B and D are in a second room; Battery Chargers 1A, 1C, and 1E and Inverters 1A, 1C, and 1E are in a third room; and Battery Chargers 1B, 1D, and 1F and Inverters 1B, 1D, and 1F are in a fourth room. Each room has its own supply and exhaust duct system which can be automatically isolated by activating isolation dampers in the ducts. The isolation dampers are activated by ionization detectors in the ducts. Fire dampers are also provided where the duct work passes through the walls between the battery and the battery charger rooms. These dampers have fusible links that melt when the temperature exceeds their setpoint.

g. Nonsegregated, metal-enclosed bus ducts are used for major circuit runs where large blocks of current from the unit auxiliary transformers to the 4160 V and 6900 V buses are to be carried. The routing of these metal enclosed bus ducts is such as to minimize their exposure to mechanical, fire, and water damage. Although none are required to be Class 1E, those portions which are located within a Class I structure have been specified to withstand design earthquakes.

h. The application and routing of control, instrumentation, and power cables are such as to minimize their vulnerability. The cables have been applied using conservative margins with respect to their current carrying capacities, insulation properties, and mechanical construction. Power and control cable insulations for use throughout the plant have been selected for the necessary combination of insulation, fire-resistant, and nonpropagation qualities, radiation, heat, and humidity resistance. Appropriate instrumentation cables are shielded to minimize induced voltage and magnetic interference. Wire and cables related to engineered safeguards and reactor protection systems are routed and installed in such a manner as to maintain the integrity of their respective redundant channels and protect them from physical damage. Administrative controls ensures that the integrity of Rockbestos Firezone R cable is maintained by requiring visual inspection of the cable whenever work is conducted in the vicinity of the cable.

   Class 1E Circuits, trays, conduit, and electrical equipment are color coded to help ensure separation of redundant circuits and the complete maintenance of power, control, and instrument channel integrity.

   Cables and equipment required for reactor protection and engineered safeguards systems are color coded as follows:

   1) Power, control, and instrumentation cables, conduit, trays, switchgear, distribution panel boards, motors, equipment cabinets, and so forth, color coded to identify their function and/or channel association. The color code scheme is as follows:

Red (Channel A)	1A Emergency Diesel Generator (Generator only)
	1D 4160 V switchgear
	1P 480 V switchgear
	1R 480 V switchgear

	1A ES MCC
	1A ES valves MCC
	1A ES screen house MCC
	1E DC panel board
	1P ES diesel generator panel board
	1A inverter
	1A vital instr. bus panel board VBA
	A ES actuation transmitter and bistable
	A ES bistable aux. relay cab. No. 1
	A ES actuation cab. No. 4
	A RPS channel (1, 5)
	A Train/I Channel HSPS
Green (Channel B)	1B Emergency Diesel Generator (Generator only)
	1E 4160 V switchgear
	1S 480 V switchgear
	1T 480 V switchgear
	1B ES MCC
	1B ES valve MCC
	1B ES screen house MCC
	1F DC panel board
	1Q ES diesel generator DC panel board
	B Train/II Channel HSPS
	1B inverter
	1B vital instr. bus panel board VBB
	B ES actuation transmitter and bistable
	B ES bistable aux. relay cab. No.2
	B ES actuation cab. No. 5
	B RPS channel (2, 6)
Yellow (Channel C)	1C ES valve MCC
	1M DC panel board
	1C inverter
	1C vital instr. bus panel board VBC
	C ES actuation transmitter and bistable
	C ES bistable aux. relay cab. No. 3
	C RPS channel (3, 7)
	III Channel HSPS
Blue (Channel D)	1D inverter
	1D vital instr. bus panel board VBD
	D RPS channel (4, 8)
	IV Channel HSPS

2) All cables have their circuit identifying number permanently affixed to each end.

3) All cable trays have their own unique number affixed to them as well as being color coded.

8.2.2.11 General Cable Considerations

a. In general, motor and transformer feeder cables are rated on a continuous basis at 125 percent of full-load current. This provides for motor and equipment operation at service factor ratings. The standards used for cable tray loading and cable ampacity derating are based on IPCEA (ICEA) Standard P-46-426, dated 1962 (Reference 11). Free air ampacities are obtained from manufacturer's data based on copper conductor temperature of 90 °C and an air ambient temperature of 40°C. Free air cable ampacities are derated for mutual heating due to multiple conductors in conduit or tray and normal maximum ambient temperature higher than 40°C.

b. Fire barriers are used at cable trays and cable runs where they go from one fire area to another fire area. There are fire barriers where the cable trays enter the Control and Auxiliary Buildings and where vertical trays pass through floor openings. Power cables routed in conduit or tray protected by fire barriers are analyzed for possible ampacity derating due to the insulating property of the fire barrier. Derating of power cables for valve operators is not considered because energization of subject cable is intermittent and therefore heat buildup is eliminated. Derating of control, control power, and instrumentation cables is not to be considered because neither type of cable carries any significant loads, near their ampacity ratings. Existing power cable in cable tray has an additional derating factor applied in cases where the tray is enclosed by a fire barrier. The additional derating factor applied is in accordance with the fire barrier manufacturer's information or laboratory tests. Other derating factors considered are number of cables in the tray, ambient temperature and cable considerations as per Reference 24.

c. Power and control cable trays are ladder type. Where there are horizontal trays passing under gratings or hatches, the top tray has a solid cover which is spaced about 3/4 inch above the tray for ventilation except where physical layout does not allow this. In general, vertical trays have covers to approximately 6 ft above their floor penetrations.

Non-Class 1E raceway, installed for Appendix R (Reference 18) compliance and Emergency Feedwater System safety grade upgrades, is designed not to become a missile hazard under SSE conditions in all seismic Class I structures. Class 1E raceway supports are seismically designed. Supports for new raceway requiring fire barriers shall be designed to allow for the fire barrier loading including attachment weight. Cable tray and conduit supports located in fire zones/areas with automatic fire suppression or in the Reactor Building need not be protected with fire barrier wraps, except to prevent heat input to a raceway protected by a fire barrier.

Fire barrier wraps have been added to cable raceways. This is described in the Fire Hazards Analysis Report (Reference 22).

Class 1E raceways installed for Appendix R (Reference 18) compliance and Emergency Feedwater System safety grade upgrades are analyzed for external hazards which include a review of mechanical systems for pipe rupture effects, the effects of seismic and rotating machinery generated missiles, and the effects of flooding (tendon access gallery). Pipe rupture protection and jet loads are also evaluated.

d. Power circuit cables ampacities were established on the basis of the maximum ambient temperature expected, the current requirements of the respective equipment, and the designed cable tray loading.

e. For original cable sizing, an ambient temperature of 50°C within the reactor containment, control, auxiliary, intermediate, fuel handling, and screen house structures, and an ambient temperature of 40°C in all other plant areas, are the design bases ambient for power cable rating. However, for recent analysis of cable ampacity, the maximum design HVAC temperature is used for the applicable location. Some cable routing for Appendix R (Reference 18) compliance and plant upgrades (e.g., EFW system modifications) utilize 40°C ambient temperatures in areas outside of the reactor containment. Also cable routing, for Appendix R in the Control Building below 322 ft. elevation, utilizes a 35°C ambient. Additional criteria for derating Rockbestos Firezone cable is described in the TMI-1 FHAR. (Reference 22) For voltage drop considerations, the resistance of a length of 20 feet of Rockbestos cable heated to 1700°F has been utilized.

f. The application and routing of control, instrumentation, and power cables are such as to minimize their vulnerability to damage from any source. All cables are designed using conservative margins with respect to their current carrying capacities, insulation properties, and mechanical construction. Power cable insulation is rated 90°C and was selected to minimize the harmful effects of radiation, heat, and humidity and to be non-flame propagating. In the Reactor Building, no interlocked armor was used in order to minimize the quantity of zinc. Appropriate instrumentation cables are shielded to minimize induced voltage and magnetic interference. Wire and cables related to engineered safeguards and reactor protection systems are routed and installed to maintain the integrity of their respective redundant channels and protect them from physical damage. Engineered safeguards cables within containment are run in conduit, which will protect them from the building spray. Stainless steel flexible hose is used at all engineered safeguards motor terminations within containment.

g. Ionization detectors as described in Section 9.9 are located in the ventilation ducts. All of the detectors are alarmed in the Control Room or the Unit 1 Processing Center. In addition, combustible vapor detectors are provided as described in Section 9.9.

h. Cable installed for Appendix R (Reference 18) compliance and Emergency Feedwater System upgrades is qualified to meet IEEE 383-1974 and Regulatory Guides 1.89 and 1.100 (References 15, 8, and 9). Safe shutdown circuits identified by the Appendix R evaluation (Reference 3) as the required cables for safe shutdown, have been routed, or rerouted, or replaced with fire rated Rockbestos Firezone R cables or protected with fire barrier wrap to comply with requirements of 10CFR50, Appendix R (Reference 18). Rockbestos Firezone cable is environmentally qualified for LOCA conditions. Nuclear safety related circuits are run entirely in Class 1E raceway. When these circuits are run in non-seismic building, they were made as much Class 1E as possible. Firezone R cable may be used in locations having existing automatic fire suppression systems and fire detection systems either as sheathed cable in cable tray or unsheathed cable in standard conduit.

Firezone R cable may be used in locations not having automatic fire suppression systems and fire detection systems as unsheathed cable in a fire rated conduit system.

Where feasible, these conduits are located such that fire debris will not damage them. Otherwise, the need for protection from debris is evaluated and protection designed if necessary.

Fire rated Rockbestos Firezone R cables may be utilized in lieu of radiant energy shields for some cables requiring protection within the reactor building.

8.2.2.12 Separation Of Redundant Circuits

a. Cabling for redundant components has been identified utilizing four different colors. Power, instrumentation, and control cables are run separately except for a few low energy 120 VAC or 125 VDC power cables which were placed in control cable trays. Redundant cables are routed separately.

   1) There is four-channel separation for the reactor protection circuits and three channel separations for engineered safeguards instrumentation circuits. This separation is maintained from the sensor to the bistable rack or RPS subassembly and between these cabinets and the logic or relay cabinets. Since input and output signals lose their channel identity, no channel separation is provided within each of the bistable cabinets.

   2) Logic output control and power cables for the operation of redundant components in safety or engineered safeguards systems are routed separately.

b. The DC control power from the station batteries is run in underground duct to the substation. Separation is maintained by barriers in manholes and in the substation control house up to the DC distribution panels. Separation is also maintained for all engineered safeguards redundant bus DC feeders.

c. The minimum physical dimensions between a given engineered safeguard channel's power, control, and instrument cable trays are approximately 7 inches vertical separation between the bottom of the top tray and top of the lower tray, and approximately 6 inches horizontal separation between adjacent sides. An effort has been made to maintain maximum separation between redundant trays, and in most cases this has been accomplished, with separation of as much as 20 ft or more. In a very few cases, the separation is approximately 12 inches; in these cases, a barrier is installed between the trays except in the Fuel Handling Building Elevation 281 and the RB Penetration Area of the Auxiliary Building Elevation 281, where water fire suppression systems directly above the cable raceways protect the circuits in lieu of the barriers. Where less than 12 inches of separation exists, engineering judgment was used to evaluate the separation on a case by case basis.

d. Inside the Control Room consoles, wiring of mutually redundant channels is separated by 6 inches minimum free air space, or a fireproofing type material barrier is installed between channels.

e. There are three different locations on the Containment Building wall where electrical penetrations are made. These three locations are physically separated by some distance. The physical separation of the penetration cartridges within a particular area is determined by the horizontal spacing of redundant engineered safeguard penetrations of 3 ft 3 inches. Engineered safeguards penetrations are located within two adjacent 90 degree quadrants but are separated into three groups within these two quadrants. The first group, which is in Quadrant II, consists of two redundant nuclear instrumentation penetrations, two redundant low-level process instrumentation penetrations, and Channel C Reactor Building fan power. The second group is in Quadrant III and is separated from the first group by 4°6' radial or 4 ft 7 3/4 inches straight-line distance between the closest penetrations inside the Reactor Building and 4 ft 11 1/4 inches outside the Reactor Building. Group two consists of two redundant nuclear instrumentation penetrations and two redundant low-level process instrumentation penetrations. Group three is also in Quadrant III but is separated from Group two by 40°5'29" radial or 44 ft 6-3/4 inches straight-line distance between closest penetrations inside the Reactor Building and 46 ft 11-1/2 inches outside the Reactor Building. Group three consists of redundant low-voltage control and Channel A and B Reactor Building fan power.

f. Separation between the circuits and cabling of pressurizer heaters groups 8 and 9 (as described in Section 8.2.3.5) is maintained up to the pressurizer heater terminal box. The remaining portion of the design (i.e., the terminal box, pressurizer heater elements, and interconnecting cable routing) will remain as it exists due to constraints imposed by the original physical construction of the equipment. The relative closeness of the pressurizer heater elements and heater bundles does not permit further physical separation.

8.2.2.13 <u>Cable Tray Loading And Separation</u>

a. 6900 V Power Cable

1) No other cable is mixed in the same tray with 6900 V power cable.

2) There shall be only one layer of cable in a tray.

3) Cable ampacity is derated in accordance with Section 8.2.2.11.

b. 4160 V Power Cable

1) No other type of cable is mixed in the same tray with 4160 V power cable.

2) There shall be only one layer of cable in a tray.

3) Cable ampacity is derated in accordance with Section 8.2.2.11.

4) Emergency feeders to 4160 V buses 1D and 1E are considered to be redundant engineered safeguards circuits.

c. 480 V Bus Tie Cable

1) No other type of cable is mixed in the same tray with 480 V bus tie cable.

2) There is only one layer of cables in a tray.

3) Cable ampacity is derated in accordance with Section 8.2.2.11.

d. 480 V Power Cable

1) DC power cable may be mixed in the same tray with 480 V power cable.

2) Control cable may be routed in the same tray with 480 V low power cable (size No. 8 and smaller), where necessity dictates. In such cases, a metal barrier is used to separate control and power cables.

3) Tray loadings do not exceed the appearance of 100 percent fill. Thermal loading has been considered leading to the use of derating factors based on an established number of cables in accordance with Section 8.2.2.11.

e. Control Cable

In general, tray loadings do not exceed the appearance of 100 percent fill. In the few cases where trays appear to exceed 100 percent, fill calculations were done to verify less than 100 percent fill and, therefore, tray loading concerns are satisfied.

f. Instrument Cable

1) In general, tray loadings do not exceed the appearance of 100 percent fill. In the few cases where trays appear to exceed 100 percent fill, calculations were done to verify less than 100 percent fill and therefore tray loading concerns are satisfied.

2) There are no other types of cables mixed in with instrumentation cabling.

8.2.3 SOURCES OF AUXILIARY POWER

8.2.3.1 Description Of Power Sources

Each auxiliary power source will have various degrees of redundancy and reliability as outlined below.

a. As described in Section 8.2.2.2, normal power supply to unit auxiliary loads will be provided through either one of the auxiliary transformers connected to the 230 kV substation buses. Power to these transformers can be provided from any one of four transmission circuits and the nuclear generating unit if operating.

b. Upon loss of the sources of power described in item a. above, power will be supplied from two automatic, fast-start diesel engine generators. These are sized so that either one can carry the required engineered safeguards load. The nameplate ratings of each emergency generator are: (1) 2750 kW at 0.8 power factor continuously with an expected availability of 95 percent providing there is an inspection every 24 months (with a 25% allowable grace period) in accordance with procedures prepared in conjunction with the applicable recommendations of the Fairbanks Morse Owners Group and those of the manufacturer for this class of stand-by service, (2) 3000 kW at 0.8 power factor for 2000 hours, and (3) 3300 kW at 0.8 power factor for not more than 30 minutes. The diesel engines are cooled by a jacket coolant system which transfers engine heat to a coolant liquid. The jacket coolant system is designed to dissipate excess heat from the engine and lube oil to the atmosphere through heat exchangers (radiators) which employ a fan driven directly from the engine. The jacket coolant temperature is maintained when the unit is not operating by a standby heater system. The function of the standby heater system is to maintain minimum jacket coolant temperature (120°F nominal) and lube oil temperature (90°F minimum). Coolant is circulated through a 24 kW standby electric heater, the lube oil heat exchanger, the water jacket, combustion air coolers, and the radiator fan gearbox oil cooler by the standby coolant pumps. An auxiliary electric heater maintains gearbox lube oil temperature at 45°F minimum. Operation of the diesel generator above 250 rpm automatically isolates the standby system, provided appropriate interlocks are satisfied.

When the unit is operating the jacket coolant temperature is controlled by a temperature control valve that directs water through the radiators or through a bypass line.

Each emergency generator will feed one of the 4160 V engineered safeguards buses. Each generator is capable of feeding the required safeguards loads of one 4160 V bus plus selected BOP manually applied emergency loads following any loss of coolant accident (LOCA). The diesel generator Engineered Safeguards block loading sequence is given on Table 8.2-11.

The diesel generator load tables, 8.2-8 and 8.2-9a show major loads on one D/G in the event the redundant diesel generator fails to start. The actual loads and loading values are tracked by C-1101-741-E510-005. See Reference 17. Diesel generator 1A is listed, but diesel generator 1B loads are similar. In all cases the total load is less than the 2000 hr. rating of 3000 KW for the diesel generator.

Sufficient fuel is stored to allow one unit to supply post accident power requirements for 7 days based on the electrical loads shown on Tables 8.2-8, 8.2-9a and C-1101-741-E510-005. The LOOP/LOCA (Table 8.2-9a) load is assumed to exist for the first 24 hours and then reduced loading is assumed to continue for the next 6 days. Fuel supplied from the main storage tank is stored at each unit in a 550 gallon diesel generator day tank. Level switches automatically control the operation of an AC and redundant DC motor driven pump to maintain day tank fuel level. Additional level switches provide high and low level alarms.

The starting air system consists of a dual drive air compressor, two air reservoirs and controls located external to the engine designed to provide air at 225 to 250 psi. Starting air is directed through a manual shut-off valve and two air start solenoid operated valves and an air distributor system in the engine. A vent valve solenoid valve closes during the starting cycle. Two pressure switches indicate starting air being applied to the engine. A pressure gauge is mounted on the instrument panel and an alarm switch is provided to signal low starting air pressure.

The distributor includes one pilot air valve for each cylinder.

The air compressor is two stages with a loadless start feature. It is normally driven by an electric motor and can be, in an emergency, driven by a diesel engine by shifting belts from the motor to the engine. The engine is electric start and is provided with a separate 12 Vdc battery and charger.

The units are located in an annex on the opposite side of the building from the 230 kV substation and transformers and are separately enclosed to minimize the likelihood of mechanical, fire, or water damage.

Each diesel engine will be automatically started upon the occurrence of the following incidents:

1) Initiation of safety injection operation.

2) Overpressure in the Reactor Building.

3) Loss of voltage or degraded bus voltage detected by the undervoltage protection scheme on the 4160 V engineered safeguards bus with which the emergency generator is associated.

    For each Diesel Generator Automatic Start, automatic safety injection actuation and automatic overpressure in the reactor building actuation are sensed via the following relays: Two out of three 63Z2A/RC1, 63Z2A/RC2, 63Z2A/RC3 or two out of the three: 63Z1B/RC1, 63Z1B/RC2, 63Z1B/RC3. Manual actuations for safety injection or overpressure in the Reactor Building is sensed via 1X2A/RC or 1X1B/RC. Loss of voltage or degraded voltage is sensed by two out of three relays 27-1 through 27-6. Upon loss of the 4160 V bus voltage, the diesel generator unit will be automatically connected to its bus. The sequence to accomplish this following the starting signal will be as follows:

    Step 1 Automatic tripping of breakers on the bus.

    Step 2 After the unit comes up to speed and voltage, the emergency generator breaker will automatically close.

    Step 3 Automatic and manual starting of equipment as required for safe plant operation.

    Loss of voltage detection and diesel breaker automatic close signals both use two out of three logic.

    If there is a requirement for safeguards system operation coincident with the loss of voltage on the 4160 V bus, Step 2 will be followed by the automatic sequential starting of safeguards equipment.

    In the event one emergency generator does not come on the line when called for, the automatic starting sequence of components associated with this generator and bus will be blocked.

    The automatic sequential loading of each diesel generator with safeguards auxiliaries will be accomplished in five blocks as described in Item c. of Section 7.1.3.2. These blocks have been selected so as to limit the maximum system voltage dip to approximately 30 percent. Safeguards control center starters have been specified to hold in at 10 percent below this value.

Starting of a diesel engine generator takes 10 seconds. For a simultaneous LOCA and loss of offsite power a delay time of 35 seconds is assumed in the safety analysis (Chapter 14, Reference 77) to allow for signal generation, electrical supply startup, injection pump startup and initiation of the pumped injection flows. The high pressure and low pressure injection systems are in the first loading block. See Table 8.2-11. If the system, rather than the emergency generators, continues to feed the safeguards buses at the time of a LOCA, safeguards loads will be started in the same five blocks in order to limit voltage dips. Safeguards loads which are running prior to the LOCA signal are not tripped and will continue to run. Therefore, core injection systems will be in operation in less than 25 seconds since diesel starting time would not then be a factor.

c. Should an engineering safeguard be followed by a loss of offsite power, time delay has been provided for the diesel generator breaker closure to assure that adequate time has elapsed since the opening of the bus feeder breakers to allow for voltage decay on the buses and for the shedding of other loads with under voltage relays.

8.2.3.2 Generator Breaker Closing Interlocks

a. The following conditions must be met in order to manually close the diesel breaker:

1. Synch. switch must be on
2. Breaker racked in
3. 81-59, 2 out of 3 matrix satisfied, diesel ready for loading
4. 86B, bus overload reset
5. 86G, Diesel Differential reset
6. Place generator breaker control switch to close when generator synchronizes with the bus

b. The following conditions must be met in order to auto close the diesel breaker:

1. Breaker racked in
2. Breaker control switch out of Pull-To-Lock
3. 81-59, matrix satisfied
4. 86B, bus overload reset
5. 86G, Diesel Differential reset
6. Safeguards bus incoming Breakers are open

8.2.3.3 Diesel Generator Trip Devices

The following tripping devices are for the diesel generators:

a. Engine Trips

1. Low lube oil pressure - idle speed (non-ES)
2. Start failure (non-ES)

3. 2 out of 3 low lube oil pressure - running
4. Engine overspeed
5. Stop pushbuttons at engine and Control Room (non-ES)
6. 86/G
7. 86B
8. 2 out of 3 high crankcase pressure (non-ES)

b. Generator Breaker Trips

1. Control switch
2. 86G Generator differential overcurrent
3. 86B Bus overload
4. 46G - Negative phase sequence (phase to phase fault)
5. 76 Fx - Field overload
6. 64G - Neutral Ground
7. 32 - Reverse power
8. K1 - Exciter Shutdown
9. 40X - Loss of Excitation

8.2.3.4 Diesel Generator Remote Controls and Status Indicators

a. Remote controls for the diesel generators are provided on the right console in the Control Room. The following controls are provided:

1. Diesel start switch
2. Synchronizing controls and indication
3. Manual start and stop pushbuttons
4. Prelube pump control
5. Exciter auto manual switch
6. Exciter manual autotransformer voltage control
7. Governor, Raise-Lower switch
8. Exciter shutdown pushbutton
9. Generator breaker control

b. The following indication is provided in the Control Room:

1. Diesel Generator Cranking Light - 250 rpm
2. Diesel Generator Running Light - 810 rpm
3. Ready to Load Light - up to voltage and frequency
4. Speed control
   Idle - 450 rpm
   High - 900 rpm
5. Engine speed
6. Wattmeter
7. VAR meter
8. Ammeter
9. Voltmeter

c. The following diesel generator status alarms are provided in the Control Room:

1. Diesel generator blocked
2. Diesel generator 1A/1B generator breaker locked out
3. Diesel fuel storage tank level LO

8.2.3.5 Power To Vital Loads And Load Shedding

All of the power sources supply power to the 4160 V bus sections which serve the engineered safeguards auxiliaries and reactor protection systems. The engineered safeguards auxiliaries and reactor protection systems have been arranged so that a failure of any single bus section will not prevent the respective systems from fulfilling their protective functions. On loss of its normal source of power, i.e., voltage failure, the associated safeguards bus will be cleared of auxiliaries and ties and the corresponding diesel generator will be started, brought up to speed and voltage, and tied to the bus automatically. In the absence of safety injection or Reactor Building emergency cooling requirements, only selected auxiliaries will automatically start. Logic and control circuitry will be fed without interruption from DC sources and inverter buses.

Following receipt of an engineered safeguards signal, selected loads are automatically tripped and are prevented from automatically restarting. In addition, loading of 4.16 kV or 6.9 kV loads during the engineered safeguard block loading sequence is not allowed by administrative control.

In the event that the diesel generators must feed the safeguards loads after a LOCA, BOP AC auxiliaries will be tripped out and will not automatically restart. The operator must manually bypass the safeguards actuation circuit after all safeguards auxiliaries are in operation and then manually enable and start BOP loads as desired when the emergency diesel generator has the capacity to power the chosen BOP load. Enabling functions can be accomplished at the safeguards panel in the Control Room.

A cross-tie is provided between the A diesel generator backed bus 1D and non-safety related buses. On an undervoltage signal to ID bus the 1N BOP 480V bus is tripped from the bus. If the A diesel generator breaker is closed and an ES signal exists, then the breaker for 1N bus cannot be closed. Four other 480V BOP buses can be fed from the 1N 480V bus.

Operating procedures provide guidance that engineered safeguards switchgear shall not be crosstied when the reactor is critical. Engineered safeguards buses will only be tied together when manually shutdown, and for maintenance or for emergency conditions as directed by approved procedures. During both normal and emergency modes of operation, these buses are normally fed from different transformers or diesel generators.

NRC NUREG-0737 (Reference 16) requires that redundant emergency power be provided to the minimum number of pressurizer heaters required to maintain natural circulation conditions in the event of a loss of offsite power. **For TMI-1, this minimum is 107 kW of pressurizer heaters.** To comply with this requirement, pressurizer heater groups 8 and 9 are both maintained above 107 kW minimum. A manual transfer scheme has been installed to transfer the source of power for pressurizer heater group 8 from the BOP source to 480 V engineered safeguards bus 1P, and vice versa. A similar manual transfer scheme will transfer pressurizer heater group 9 from the BOP source to engineered safeguards bus 1S, and vice versa. Each manual transfer scheme has double isolation consisting of a disconnect device in series with a circuit breaker at each end of the transfer. Figure 8.2-5 is a schematic representation of these transfer schemes.

During normal plant operation, with offsite power available, all pressurizer heaters are powered from the BOP sources. Upon a loss of offsite power, manual transfers can be made, within two hours time, to enable the pressurizer heaters to be powered by the onsite emergency diesel generators. Procedures call for tripping nonessential loads to permit this. When offsite power is restored, the pressurizer heaters are transferred back to the BOP source.

Undervoltage relays connected to each set of 480 V engineered safeguards bus potential transformers initiate tripping of the respective pressurizer heater's engineered safeguards circuit breaker in the event of low engineered safeguards bus voltage. An engineered safeguards actuation signal trips, but does not lock out, each engineered safeguards circuit breaker to the pressurizer heaters. This trip is annunciated in the Control Room.

8.2.3.6 Reliability Considerations

Upon a total system Grid blackout, there are two remaining AC power sources, i.e., the unit (if the unit does not trip) and the diesel engine generators (including the SBO diesel generator), plus the station batteries. The coincident failure of the remaining power sources and a system blackout is not credible.

Diesel generator reliability is achieved with an inspection every 24 months (with a 25% allowable grace period) in accordance with procedures prepared in conjunction with the applicable recommendations of the Fairbanks Morse Owners Group and those of the manufacturer for this class of standby service.

For reliability target and discussion, see Section 8.5.1.3. Records of diesel generator operational and failure data are kept in compliance with Regulatory Guide 1.108, Section 3.a (Reference 10).

In accordance with diesel engine manufacturer's recommendations, the emergency diesel generator shutdown on high crankcase pressure is blocked during ES operation, and the pressure switches are mounted in the vertical plane. The high crankcase pressure shutdown function will operate during non-ES operation. Emergency diesel generator high crankcase pressure alarm is provided for all modes.

DELETED TABLES

Table 8.2-1 - Electrical - 480 V Control Center 1A Engineered Safeguard Loads

Deleted - See Drawing No. B-201043, latest revision.

Table 8.2-2 - Electrical - 480 V Control Center 1A Engineered Safeguard Valve Loads

Deleted - See Drawing No. B-201052, latest revision.

Table 8.2-3 - Electrical - 480 V Control Center 1C Engineered Safeguard Valve Loads

Deleted - See Drawing No. B-201069, latest revision.

Table 8.2-4 - Electrical - 480 V Control Center 1B Engineered Safeguard Loads

Deleted - See Drawing No. B-201044, latest revision.

Table 8.2-5 - Electrical - 480 V Control Center 1B Engineered Safeguard Valve Loads

Deleted - See Drawing No. B-201053, latest revision.

Table 8.2-6 - Electrical - 480 V Control Center 1A Engineered Safeguard Screen House Loads

Deleted - See Drawing No. B-201062, latest revision.

Table 8.2-7 - Electrical - 480 V Control Center 1B Engineered Safeguard Screen House Loads

Deleted - See Drawing No. B-201063, latest revision.

Table 8.2-9b - Major Diesel Generator Loads Typical of Single Transformer Operation with Subsequent Large LOCA

Deleted

Table 8.2-10 - Diesel Generator Preventative Maintenance Tasks

Deleted

Table 8.2-12 - Station Battery Loading Battery A Load

Deleted – See Calculation No. C-1101-734-5350-003, latest revision.

Table 8.2-13 - Station Battery Loading Battery B Load

Deleted – See Calculation No. C-1101-734-5350-003, latest revision.

TABLE 8.2-8
(Sheet 1 of 1)

MAJOR DIESEL GENERATOR LOADS TYPICAL OF
LOSS OF OFFSITE POWER ONLY
1A DIESEL GENERATOR LOADS (1B diesel not available)
(Actual Loading and Loading Values Tracked by C-1101-741-E510-005$_{(1)}$)

Power Supply Bus - 4160V Switchgear 1D

Emergency Feedwater Pump, EF-P-2A
Make-Up Pump, MU-P-1A or MU-P-1B
Reactor Building Emergency Cooling River Water Pump, RR-P-1A
Transformers 1P & 1R Losses

Power Supply Bus - 480V Switchgear 1P

Nuclear Services Closed Cooling Water Pump, NS-P-1A

Power Supply Bus - 480V Switchgear 1R

Secondary Services River Water Pump, SR-P-1A
Screen Wash Pump, SW-P-1A
Nuclear Services River Water Pump, NR-P-1A

Power Supply Bus – 1A ES Motor Control Center

Power Supply Bus – 1A ES (Screenhouse) Motor Control Center

Power Supply Bus – 1A ES Valves
Power Supply Bus - 1C ES Valves Control Center

Reference:

1. C-1101-741-E510-005, “Loading Summary of Emergency Diesel Generator and Engineered Safeguards Buses.”

TABLE 8.2-9a
(Sheet 1 of 2)

MAJOR DIESEL GENERATOR LOADS TYPICAL OF LOSS OF
OFFSITE POWER WITH LARGE LOCA
1A DIESEL GENERATOR LOADS (1B DIESEL NOT AVAILABLE),
(Actual Loads and Loading Values tracked by C-1101-741-E510-005$_{(1)}$)

Power Supply Bus - 4160V Switchgear 1D

Decay Heat Removal Pump, DH-P-1A
Emergency Feedwater Pump, EF-P-2A
Make-Up Pump, MU-P-1A or MU-P-1B
Reactor Building Emergency Cooling
River Water Pump, RR-P-1A
Reactor Building Spray Pump, BS-P-1A
Transformers 1P & 1R Losses

Power Supply Bus - 480V Switchgear 1P

Decay Heat Closed Cooling Water Pump, DC-P-1A
Nuclear Services Closed Cooling Water Pump, NS-P-1A
Nuclear Services Closed Cooling Water, NS-P-1B
CB Water Chiller, AH-C-4A

Power Supply Bus - 480V Switchgear 1R

Secondary Services River Water Pump, SR-P-1A
Screen Wash Pump, SW-P-1A
Nuclear Services River Water Pump, NR-P-1A
Nuclear Services River Water Pump, NR-P-1B
Decay Heat River Water Pump, DR-P-1A

TABLE 8.2-9a
(Sheet 2 of 2)

MAJOR DIESEL GENERATOR LOADS TYPICAL OF LOSS OF
OFFSITE POWER WITH LARGE LOCA
1A DIESEL GENERATOR LOADS (1B DIESEL NOT AVAILABLE),

Power Supply Bus – 1A ES Motor Control Center

Power Supply Bus – 1A ES (Screenhouse)
Motor Control Center

Power Supply Bus – 1A ES Valves
Motor Control Center

Power Supply Bus - 1C ES Valves
Motor Control Center

Reference:

1. C-1101-741-E510-005, "Loading Summary of Emergency Diesel Generator and Engineered Safeguards Buses."

TABLE 8.2-9b

Table 8.2-9b
Deleted

TABLE 8.2-11
(Sheet 1 of 1)

Engineered Safeguards Loading Sequence

Loading Sequence	Description
Block 1	Diesel Generator Starts & ES Bus Load Shedding Actuates Makeup Pump (High Pressure Injection), Decay Heat Pump (Low Pressure Injection), Most ES Motor Operated Valves, and Permanently connected ES loads including: Emergency Lighting, Inverters, Control Building Lighting, Radiation Monitors Battery Chargers, and Miscellaneous Heat Trace and Unit Heaters
Block 2	Reactor Building Ventilation Units, Reactor Building Emergency Cooling - River Water Pump
Block 3	Nuclear Services Closed Cooling Pump, Nuclear Services River Water Pump, Decay Heat Closed Cooling Pump, Decay Heat River Water Pump, Miscellaneous Motor Operated Valves
Block 4	Reactor Building Spray Pump, NS/DC Pump Area Fan, Screen House Fan
Block 5	Emergency Feedwater Pump
Manually Applied Loads	Instrument Air Compressor, Spent Fuel Pump Control Building Ventilation Supply Fan, Control Building Exhaust Fan, Control Building Chiller Penetration Cooling Fan, Chilled Water Supply Pump

8.3 TESTS AND INSPECTIONS

The diesel engine generators are controlled from a section of the main control console located in the Control Room. Provision has been made on the control console to manually initiate a fast start of any of the generators with closure of the associated air circuit breakers connecting the generator to its 4160 V engineered safeguards auxiliary bus with the bus deenergized. Testing of this system may be done by the Control Room operator at his convenience any time the units are not otherwise running, with due regard for reactor auxiliaries in use. Periodic testing of the diesel generators is required per the Technical Specifications.

In response to NRC Generic Letter 84-15 (Reference 19), the number of diesel generator cold fast starts has been reduced to enhance the reliability of the diesel generators by minimizing the degradation due to testing. Technical Specification surveillances require Diesels A and B to be cold fast started one time each on a refueling interval basis. Other planned tests or routine diesel starts follow the manufacturer's recommendations for pre-lube and warming in preparation for starting the diesels. TMI-1 Technical Specifications do not require tests of the emergency diesels for emergency cooling system operability.

The 230 kV circuit breakers can be inspected, maintained, and tested as follows:

a. The 230 kV transmission line circuit breakers are tested on a routine basis. This can be accomplished on the breaker-and-a- half scheme without removing the transmission line from service.

b. The 230 kV generator circuit breakers can be tested with the generator in service.

Transmission line protective relaying can be tested on a routine basis. Generator protective relaying will be tested when the generator is offline. The 4160 V circuit breakers, motor starters, and associated equipment can be tested in service by opening and closing the circuit breakers or starters so as not to interfere with operation of the station.

Emergency transfers to the various emergency power sources can be tested on a routine basis to prove the operational ability of these systems. Each inverter for the 120 V vital power system can be tested by momentarily opening its normal ac source.

Station battery load testing and surveillance of voltage, specific gravity and liquid levels are required per the Technical Specification. The ungrounded DC system has detectors to indicate when there is a ground existing on any leg of the system. A ground on one leg of the DC system will not cause any equipment to malfunction.

Grounds can be located by a logical isolation of individual circuits connected to the faulted system, while taking the necessary precautions to maintain the integrity of the vital bus supplies.

8.4 QUALITY CONTROL

The Quality Program for TMI-1 is as described in the licensee's Quality Assurance Topical Report (Reference 1).

8.5 STATION BLACKOUT EVALUATION

TMI-1 has been evaluated against the requirements of the Station Blackout rule 10CFR50.63 (Reference 18) using guidance from NUMARC 87-00 – (Reference 12) "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors." The evaluation is documented in the TMI-1 Station Blackout Report (Reference 5).

8.5.1 STATION BLACKOUT DURATION

NUMARC 87-00, Section 3 (Reference 12) was used to determine a proposed SBO duration of four hours.

The following plant factors were identified in determining the proposed station blackout duration:

1. AC Power Design Characteristic Group is P2 based on:

    a. Expected frequency of grid related LOOPS does not exceed once per 20 years;

    b. Estimated frequency of LOOPS due to extremely severe weather places the plant in ESW Group 3;

    c. Estimated frequency of LOOPS due to severe weather places the plant in SW Group 2;

    d. The offsite power system is in the I1/2 Group.

2. The emergency AC power configuration group is C based on:

    a. There are two emergency AC power supplies not credited as alternate AC power sources:

    b. One emergency AC power supply is necessary to operate safe shutdown equipment following a loss of offsite power.

3. The target EDG reliability is 0.975.

    a. EDG reliability will be determined in accordance with NSAC-108 (Reference 13) methodology. This represents a change from the TMI-1 commitment to Regulatory Guide 1.108 (Reference 10) operational and failure data records as described in the GPUN October 17, 1984 response to NRC Generic Letter 84-15. (Reference 21)

    b. A target EDG reliability of 0.975 was selected based on having a nuclear unit average EDG reliability for the last 100 demands greater than 0.95, consistent with NUMARC 87-00, Section 3.2.4 (Reference 12).

4. An alternate AC (AAC) power source is utilized at TMI-1. The AAC meets the criteria specified in Appendix B to NUMARC 87-00 (Reference 12).

   This AAC capability is provided by the SBO diesel generator (what once was one of the TMI-2 Emergency Diesel Generators). This diesel generator is a TMI-1 asset, but is located in the TMI-2 diesel generator building. Exelon's easements will assure access to this diesel generator.

8.5.2 ALTERNATE AC (AAC) POWER SOURCE

The AAC power source has been designed so that it will be available within ten minutes of the onset of the station blackout event, and it has sufficient capability and capacity to operate systems necessary for coping with a station blackout for the required station blackout duration of four hours to bring the plant to and maintain it in safe shutdown. The AAC will be manually started from the TMI-1 Control Room. Circuit breakers necessary to bring power to a safe shutdown bus are capable of being actuated in the Control Room within that period. Class 1E Battery capacity, compressed air, and containment isolation were not specifically evaluated because those services can be powered from the AAC power source. The AAC system and components are not required to meet Class 1E or safety system requirements. SBO components and subsystems are physically protected against the effects of likely weather-related events, that may initiate the loss of off-site power event.[1] The AAC has an independent air start system and fuel oil system. There is also a separate DC power source that supplies the AAC and its associated breaker control. Two breakers, one that is non-Class 1E and one that is Class 1E, separate the AAC supply from the 4160 V Engineered Safeguards buses (see Drawing E-206-011). Failure of AAC components will not adversely affect Class 1E AC power systems. The AAC source will not normally be connected to the preferred or on-site emergency power system. No single active failure or weather-related event will disable both the emergency on-site AC power sources and simultaneously fail the AAC power source. The AAC system will not automatically load shutdown equipment on the ES bus; manual loading will be employed. Once the AAC Supply is providing power to 4 kV ES Bus 1E or 1D, the operator actions are essentially identical to that under a loss of offsite power with only one Emergency Diesel Generator operating, except for restoration of offsite power.

Alternate AC (AAC) Testing – Every refuel period One safe shutdown bus (1D or 1E) will be tested. Testing will verify the capability of the AAC source to provide power to the selected safe shutdown bus.

---

1 The initiating event is assumed to be a loss of off-site power (LOOP) at a plant site resulting from a switchyard related event due to random faults, or an external event, such as a grid disturbance, or a weather event that affects the off-site power system either throughout the grid or at the plant. LOOPS caused by fire, flood, or seismic activity are not expected to occur with sufficient frequency to require explicit criteria and are not considered (Source: NUMARC 87-00, Rev. 01, Section 2.3.1(1), “Initiating Event/Assumptions”).

8.5.3 Condensate Inventory for Decay Heat Removal

It has been determined from Section 7.2.1 of NUMARC 87-00 (Reference 12) that 56,804 gallons of water are required for decay heat removal for four hours (Reference 20). The minimum permissible condensate storage tank level per Technical Specification requirements provides 150,000 gallons of water for each of two tanks, which exceeds the required quantity for coping with a four hour station blackout.

8.5.4 Effects of Loss of Ventilation

The AAC power source will provide power to HVAC systems serving dominant areas of concern and the Control Room. Therefore, the effects of loss of ventilation were not specifically assessed in the evaluation.

8.5.5 Reactor Coolant Inventory

The AAC source will power the necessary make-up systems to maintain adequate reactor coolant system inventory to ensure that the core is cooled for the required coping duration.

8.6 REFERENCES

1. EG C-1A Quality Assurance Topical Report.

2. Deleted

3. G/C Report: Appendix R Safe Shutdown Equipment and Circuit Evaluation Summary Report, August 15, 1985.

4. IEEE Report No. NSG/TCS/SC4-1, entitled: "Proposed IEEE Criteria for Class 1E Electrical Systems for Nuclear Power Generating Stations," dated June, 1969.

5. GPU Nuclear Report 990-1879: TMI-1 Station Blackout Evaluation.

6. C-1101-700-E510-010, “TMI-1 AC Voltage Regulation Study.”

7. Proposed AEC Criteria 11, 24, and 39, July 11, 1967.

8. Reg Guide 1.89, Qualification of Class 1E Equipment for Nuclear Power Plants.

9. Reg Guide 1.100, Seismic Qualification of Electric Equipment for Nuclear Power Plants.

10. Reg Guide 1.108, Periodic Testing of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants.

11. IPCEA(ICEA) Standard P-46-426, 1962, Power Cable Ampacities Vol 1 Copper Conductors, reprinted as IEEE S-135, 1984.

12. NUMARC 87-00, Guidelines and Technical Basis for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors.

13. NSAC 108 The Reliability of Emergency Diesel Generators at US Nuclear Power Plants.

14. IEEE 279, Proposed Criteria for Nuclear Power Plant Protection Systems, August 1968.

15. IEEE 383-1974, Standard for Type Testing of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

16. NUREG 0737, Post TMI Requirements.

17. C-1101-741-E510-005, Loading Summary of Emergency Diesel Generator and Engineered Safeguard Buses.

18. Code of Federal Regulations, 10 CFR 50, 50.63, Appendix A and Appendix R.

19. Generic Letter 84-15, Proposed Staff Actions to Improve and Maintain Diesel Generator Reliability.

20. C-1101-421-E540-012, Station Blackout – Condensate Inventory Required for Decay Heat Removal Up to 3000 MW(t).

21. Response to NRC GL 84-15, GPUN Letter dated October 17, 1984.

22. TMI-1 Fire Hazards Analysis Report 990-1745.

23. TMI Engineering Standard ES-037T TMI-1 Voltage Criteria.

24. C-1101-770-E420-018, Derating of Cable Ampacity Due to Raceway Fire Barriers.

25. C-1101-734-5350-003, TMI-1 Battery Capacity Sizing and Voltage Drops for DC System.