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8.0 ELECTRIC POWER

8.1 INTRODUCTION

The electric power systems of the Quad Cities Station Units 1 and 2 are designed to generate and transmit electric power for the supply of customer needs utilizing the power network of the PJM Interconnection, L.L.C. (PJM – Pennsylvania Jersey Maryland). The offsite electric power system connections to Quad Cities Station are described in Section 8.2. The onsite electric power system is described in detail in Section 8.3.

8.1.1 Design Bases

The station electrical power system is designed to provide a diversity of dependable power sources which are physically isolated so that any one failure affecting one source of supply will not propagate to alternate sources. The station auxiliary electrical power system is designed to provide electrical and physical independence and an adequate number of power supplies for startup, operation, shutdown, and for other station requirements which are important to safety.

In the event of total loss of auxiliary power from offsite sources, auxiliary power will be supplied from diesel generators located onsite. This power source is physically independent from any normal power system. Each power source, up to the point of its connection to the auxiliary power bus, is capable of complete and rapid electrical isolation from any other sources. Loads important to plant safety are split and diversified between switchgear sections, and protective relays and circuit breakers are provided for timely location and isolation of system faults.

Station batteries are provided as a final source of power for specific vital dc loads.

8.1.2 Offsite Power Systems — Summary Description

The CECo transmission system is connected to the Eastern Interconnection Transmission Network. Five 345-kV transmission lines connect the station to the transmission system, as shown in Figure 8.2-1. Electric energy generated at the station is stepped up to 345-kV by the main power transformers and fed into the station's 345-kV transmission terminal ring bus (Figure 8.2-2), which is also connected to the five transmission lines.

The 345-kV ring bus provides power to two reserve auxiliary power transformers. Each reserve auxiliary transformer has sufficient capacity to handle the auxiliary power requirements of one unit. Each of these auxiliary power supplies is available, through circuit breaker switching, to both Division I and the Division II emergency auxiliary equipment of both units, and therefore, serves as a redundant offsite source of auxiliary power.

Auxiliary power for each unit is also supplied from the unit auxiliary power transformer, which is connected to the generator leads. Auxiliary power can also be supplied to both units by backfeeding through the U1(U2) main power transformer and the U1(U2) unit auxiliary transformer after removal of the generator links.

8.1.3 Onsite Power Systems — Summary Description

The onsite power systems are designed to generate electric power which is distributed to the offsite power system, and to provide an independent source of onsite power for the onsite station auxiliary electric power system. The onsite ac distribution system has nominal ratings of 13.8 kV, 4160 V, 480/277 V and 208/120 V.

The onsite power system provides a reliable source of power for the reactor recirculation pumps and other auxiliaries during normal operation, and for engineered safety features during abnormal and accident conditions. For further information about onsite ac distribution refer to Section 8.3.1. For specific ac loads refer to Tables 8.3-1, 8.3-2, and 8.3-3.

The onsite auxiliary electric power system is designed to provide reliable power to those auxiliaries necessary for power generation and to those auxiliary systems important to nuclear safety. In the event of total loss of auxiliary power, the auxiliary power required for safe shutdown is supplied from three standby emergency diesel generators located onsite. There is one dedicated diesel generator for each unit plus a swing generator that can be utilized by either unit. In the event of a total loss of all alternating current (Station Blackout event), the auxiliary power required for safe shutdown is supplied from two standby diesel generators located in the Station Blackout Building.

Startup auxiliary power is provided through the reserve auxiliary power transformers via any one or a combination of the five 345-kV transmission lines which connect the station to the offsite system.

In addition to the ac power systems, each unit has three dc power systems, each with separate batteries (nominally 250 Vdc, 125 Vdc, and 24/48 Vdc), that provide power to dc loads such as motor-driven pumps and valves, control power for equipment such as relays and circuit breakers, and power to the Nuclear Instrument Supply Systems. Section 8.3.2 describes the dc distribution system with dc loads shown in Tables 8.3-4 and 8.3-5.

8.2 OFFSITE POWER SYSTEM [8.2-1]

The offsite power system consists of the Commonwealth Edison Company (CECo), MidAmerican Energy Company (MEC) and ITC Midwest's transmission network. Several transmission lines from the network are routed to Quad Cities Station and are interconnected at the site switchyard. The transmission network is designed for reliable and stable operation over a wide range of operating conditions including transmission line failures.

8.2.1 Description

Quad Cities station is connected to the CECo, MidAmerican Energy Company (MEC), and ITC Midwest's transmission network. Power is supplied to or from the transmission network through a switchyard that is common to both units. The distribution of power to Units 1 and 2 is accomplished through a 345-kV system. The 345-kV switchyard consists of the buswork, disconnects, and breakers necessary to control station power inputs and outputs. [8.2-2]

8.2.1.1 Transmission System

The five transmission lines which interconnect the station leave on three separate transmission corridors and then diverge through the CECo transmission network. The probability of losing the offsite electric power supply has been minimized by the design of the CECo transmission system. Interconnections to neighboring systems also increase reliability. As of December 31, 1990, the CECo transmission systems included ninety-three 345-kV lines totaling 2615 miles, and three 765-kV lines totaling 152 miles. The transmission system is interconnected with neighboring electric utilities over 29 tie lines: nine 138-kV, nineteen 345-kV, and one 765-kV. [8.2-3]

8.2.1.2 Transmission Interconnections

The Commonwealth Edison transmission system is connected to the Eastern Interconnection Transmission Network and is under the control of Regional Transmission Organization (RTO) – PJM Interconnection L.L.C. (PJM – Pennsylvania Jersey Maryland).

8.2.1.3 Switchyard

The Units 1 and 2 reserve auxiliary transformers are connected to the offsite network in the 345-kV switchyard. A 345-kV ring bus is interconnected with seven sources of power: Unit 1 and 2 outputs through their main transformers, and five 345-kV transmission lines. [8.2-5]

The ring bus is composed of nine, three-phase buses, separated by nine circuit breakers. This design provides reliability, in that, as long as the ring is closed, each line or transformer has two sources of power. This design also allows isolating a load for maintenance without interrupting power to other loads. The breakers provide fault isolation of any load or source. Any fault will cause at least two breakers to open to isolate the problem. Disconnects are provided on either side of each breaker, and on each bus tap (input or output) to allow taking a line or transformer out of service while maintaining ring bus integrity for maximum reliability.

Auxiliary power can be supplied from four separate sources: Units 1 or 2, the 345-kV transmission systems, and the diesel generators. Each unit has one reserve auxiliary transformer and one unit auxiliary transformer. The reserve auxiliary transformer has sufficient capacity to handle the normal auxiliary power needs (with the load divided between the unit auxiliary and reserve auxiliary transformers as described in Section 8.3) of one unit and the emergency shutdown auxiliary equipment needs of the other unit as defined in Section 8.3. Each of these auxiliary power supplies (reserve auxiliary transformers) is available, through circuit breaker switching, to the Division I or II emergency auxiliary equipment of both units and therefore serves as a redundant offsite source of auxiliary power. Under single transformer operation, administrative controls ensure adequate system voltages are maintained and equipment ratings or short time overload capabilities of the reserve and unit auxiliary transformers and the 3000-A and 4100-A bus ducts are not exceeded. The design capability of the 4KV Division I and II crossties is limited by the 849A and 800A cable ampacity respectively. The crosstie between buses 14-1 and 24-1 has differential relays for cable fault protection. The crosstie between 13-1 and 23-1 has overcurrent (short circuit) and differential relays for overload and cable fault protection. Overload protection is also provided through administrative control which limits the crosstie load to 600A. The rating of the Unit 1 auxiliary transformer is 51.5 MVA continuous at 65°C rise with forced air (FA). The rating of the Unit 2 auxiliary transformer is 62.5 MVA continuous at 65°C rise with forced air (FA). The Unit 1 and Unit 2 reserve auxiliary transformers rating is 62.5 MVA continuous at 65°C rise with two staged forced air cooling. [8.2-6]

The auxiliary power supply for Unit 1 is divided between a unit auxiliary transformer connected to Unit 1 generator leads and the Unit 1 reserve auxiliary transformer connected to the 345-kV ring bus. The auxiliary power supply for Unit 2 is divided between a unit auxiliary transformer connected to Unit 2 generator leads and the Unit 2 reserve auxiliary transformer connected to the 345-kV ring bus. [8.2-7]

The switchyard has been located to avoid interaction with the site meteorological towers. The heights of the two meteorological towers are 300 and 400 feet. The shortest distance between any of these towers and the switchyard and transmission lines is more than 500 feet.

8.2.2 Analysis [8.2-8]

The CECo, MidAmerican Energy Company (MEC) and ITC Midwest's transmission networks have been designed to maintain their availability at acceptable levels. Analyses have been performed to demonstrate that electrical failures in the network would not result in unstable operation.

8.2.2.1 Availability Considerations of the Transmission Network

The offsite power sources provide sufficient capacity and capability (see Section 8.3) to start and operate safety-related equipment to ensure that the fuel design limits and the design conditions of the reactor are not exceeded during normal operation and the reactor core can be cooled and maintained in a safe condition in the event of postulated accidents. Because the sources to the site are normally energized, they are immediately available to the station. The ratings of the five transmission lines connected to the station are as listed in

Table 8.2-1. These values are typical values given during the 1992 UFSAR Rebaseline. The values can be changed periodically by System Protection Department as ComEd system loading changes. System Protection should be consulted for present values.

The offsite power sources for the station auxiliary power system provide redundancy, as well as electrical and physical independence, so that no anticipated single event can cause a simultaneous outage of all sources during operation, accident, or adverse environmental conditions. While it is highly unlikely that all transmission lines could be out of service simultaneously, such an event would not jeopardize safe shutdown of the station because the onsite standby diesel generators would be able to supply the necessary power to the systems required for safe shutdown (see Section 8.3). [8.2-9]

One of the functions of PJM is to ensure that the transmission system is reliable and adequate.

Transmission line L0405 crosses over transmission lines L0402 and L0404, and has one transmission tower between the two crossover points. Transmission lines L0401 and L0403 do not crossover any other lines in the switchyard area.

8.2.2.2 Stability Analysis

Commonwealth Edison Company's transmission system is designed to withstand the sudden outage of large amounts of generating capacity. The system is designed to compensate for the simultaneous loss of more than one of its largest generating units. This is possible in part because CECo has high capacity interconnections with neighboring companies. Several of these are 345-kV ties. The transmission for Quad Cities is at 345-kV, including two ties to the 345-kV network in Iowa. Commonwealth Edison Company's nonsimultaneous, first contingency import capability for the summer of 1991 varied from 450 MW to 3800 MW, depending on the direction. Commonwealth Edison Company's load and capability statement dated February 22, 1991 lists the summer net generating capacity as approximately 22,000 MW. [8.2-11]

The Quad Cities units represent about 5.2% of system capability considering these interconnection supplies and internal generation reserves. The stability of the system is continuously monitored by CECo. Currently, the system is capable of compensating for a loss of generating capacity more than that corresponding to the simultaneous loss of the two largest units in the system, Byron Units 1 and 2 each having a generating capacity of 1120 MW.

Quad Cities Station and system design for stability and circuit isolation will prevent the sudden loss of one unit at Quad Cities from causing the second unit to trip. This has been confirmed by power flow and stability studies.

Assuming one or both of the units are tripped when carrying full load, the high voltage lines at the station will continue to be energized from the transmission system. Power to replace this loss will be supplied by CECo's interconnected transmission system and its internal reserve. [8.2-12]

The auxiliary power supply from the 345-kV transmission system is protected against the effect of unplanned outages by the diversity of five separate 345-kV circuits and two major generating units feeding into a ring bus in the switchyard at the station. See Figures 8.2-1 and 8.2-2.

As a result of an NRC request, a site-specific analysis was made to determine system voltages under various system conditions, including severely degraded conditions.

The voltage level of the bus supplying the reserve auxiliary power transformers is determined by the availability of a few specific generators and transmission lines (key facilities) and is also dependent upon the system load level. The greatest reduction occurs during heavy loads with the coincident outage of several key facilities, whereas, very little reduction occurs during minimum system loads with or without the key facilities.

The Commonwealth Edison Company System Planning Department issues System Planning Operating Guides (SPOG) in order to provide reliable operation of the generation and bulk power transmission systems. The Guides are periodically issued providing guidance to generating station personnel covering a wide range of normal, abnormal, and emergency conditions on the bulk power system. [8.2-13]

The recommended operating voltage level maintained on the 345 kV bus for Quad Cities Units 1 & 2 is provided by System Planning Operating Guide SPOG: 1-1, Generation Stations Operating Voltage Level.

The critical control voltages in the plant, assuming the worst case auxiliary power distribution system loading, are based on the second level undervoltage relay setpoints as discussed in Section 8.3.1.8.

Table 8.2-1

THE RATINGS OF OFFSITE TRANSMISSION LINES*

Line	Summer Normal (amps)	Summer Emergency (amps)
0401	1620	2000
0402	1675	1675
0403	2065	2560
0404	2260	2580
0405	1600	1760

* Typical values only - consult System Protection Department for present values.

Table 8.2-2

Deleted

8.3 ONSITE POWER SYSTEMS

The station electrical distribution system is designed to include sufficient power sources and redundant buses to provide reliable electrical power during all modes of station operation and shutdown conditions.

The following sections provide detailed descriptions of each onsite power system.

8.3.1 AC Power Systems

The onsite ac power system consists of two main generators, two main step-up transformers, two unit auxiliary transformers (UATs), two reserve auxiliary transformers (RATs), distribution buses, three standby emergency diesel generators (DGs), and two standby station blackout (SBO) diesel generators. The distribution system has nominal ratings of 13.8 kV, 4160 V, 480/277 V, and 208/120 V. [8.3-1]

The offsite ac power system supplies power to the onsite auxiliary power system through two RATs (one per unit, TR-12 and TR-22). Power to non-plant site facilities is supplied by transformers TR-81 and TR-82. Refer to Section 8.2 for more detailed information on the offsite distribution system. Offsite power can also be supplied by backfeeding through the main power transformer and the unit auxiliary transformer after the main generator links have been removed. Bus loading assumed for offsite power supply requirements are listed in Table 8.3-6. [8.3-2]

The auxiliary power system provides adequate power to operate the station auxiliary loads necessary for station operation. The station auxiliary buses can also be connected, by appropriate switching sequences, to the DGs (emergency and SBO) which provide power in the event of total loss of auxiliary power from offsite sources. The DGs are physically and electrically independent from the offsite power system. Each power source, up to its connection to the auxiliary bus, is capable of complete and rapid electrical isolation. [8.3-3]

Plant layout provides physical separation of bus sections, switchgear, interconnections, feeders, power centers, motor control centers (MCCs), and other system components. Loads important to plant safety are split and diversified between switchgear sections, and protective relays and circuit breakers are provided for timely location and isolation of system faults. For more detailed information on fault isolation refer to Section 8.3.1.2. These circuit breakers are sized to provide adequate protection for downstream components and to interrupt anticipated fault currents that could occur during normal operation. [8.3-4]

The multiplicity of lines feeding the RATs, the redundancy of transformers and buses within the plant, and the divisions of critical loads between buses yield a system that has a high degree of reliability and integrity. Physical separation of buses and service components limits or localizes the consequences of electrical faults or mechanical accidents occurring at any point in the system. However, the possibility of loss of offsite power is foreseen and provisions for any such event have been made. [8.3-5]

On loss of auxiliary power the reactor will scram, and if auxiliary power is not restored immediately, the emergency DGs are designed to automatically start and carry the vital loads for an indefinite period. The buses are arranged so that the DGs are easily connected to the vital loads. In the event that the emergency DGs do not start automatically, the SBO DGs are available to be manually started to provide power to the vital loads.

Auxiliary power is normally supplied by the UAT and the RAT, with the load divided between them. These transformers supply power to the equipment used to maintain a safe and operable plant. It is very improbable that both electrical power sources would be lost simultaneously because each is supplied from a different source.

If auxiliary power were lost, the coastdown of the recirculation pumps would decrease reactor power rapidly. In addition, within a few seconds the reactor would scram due to low voltage to the reactor protection system (RPS) and the main steam line isolation valves would close due to low reactor pressure, if the reactor mode switch were left in RUN.

Steam isolation by closure of turbine stop and bypass valves due to loss of condenser vacuum is slower than by closure of main steam isolation valves, because the coastdown of the main condenser cooling water is offset by the decreasing turbine steam flow, which follows the decreasing reactor power. Therefore, the transient is less severe than that addressed in Section 15.2.

At no time will loss of auxiliary power prevent a reactor scram since stored pneumatic energy and reactor pressure are the driving forces of the control rods. In addition, the DGs and station batteries are available for emergency operation of reactor instrumentation, isolation valves, emergency core cooling system (ECCS) pumps, and other critical systems.

A diagram of the principal elements of the auxiliary electrical system is provided as Figure 8.3-1, and the major equipment is listed in Table 8.3-1. Auxiliary power is provided by both the UAT connected to the unit generator isolated phase bus and the RAT connected to the 345-kV bus at Quad Cities, as shown in Figure 8.3-1. The auxiliary loads are split between the auxiliary power transformers. The auxiliary transformers step down the voltage to 4160 V to supply the auxiliary buses.

In the event that the 345-kV switchyard and the unit generator were incapacitated, the DGs would provide another independent source of auxiliary power. The DGs have the capacity for operation of systems required to shutdown the unit and maintain it in a safe shutdown condition until offsite power is restored. Offsite power would then be used to maintain a safe shutdown condition.

8.3.1.1 Main Generator 18-kV System and Other Offsite and Onsite System Interfaces

The main generator and 18-kV system provide electrical power to station auxiliaries via the UAT, and for distribution to the CECo, MidAmerican Energy Company (MEC) and ITC Midwest transmission systems via the main transformer. [8.3-6]

The other onsite and offsite interfaces addressed in this section are RATs TR-12 for Unit 1 and TR-22 for Unit 2. Each of these transformers supplies electrical power from the 345-kV switchyard under both normal and emergency conditions.

8.3.1.1.1 System Description

The main generator of each unit is connected through an isolated-phase bus to the low side of the main transformer and the high side of the UAT. The high side of the main transformer is connected to the offsite power system and the low side of the UAT is connected to the onsite power system.

The other onsite and offsite interfaces are through transformers (TR-12, TR-22, TR-81, and TR-82). The high sides of these transformers are connected to the 345-kV switchyard. The low sides of TR-12 and TR-22 are connected to the 4160-V system of Units 1 and 2 respectively. The low sides of TR-81 and TR-82 are connected to the 13.8-kV distribution system for non-plant loads.

8.3.1.1.2 Systems Components

The major components of each unit's main generator and 18-kV systems are the main generator, the isolated phase bus, the main transformer, and the UAT.

8.3.1.1.2.1 Main Generator

The main generator converts the rotational mechanical energy of the main turbine into electrical energy. The main generator rating is given in Table 8.3-1. [8.3-7]

8.3.1.1.2.2 Isolated Phase Bus

The 34,256 Amp isolated-phase bus connects the main generator to the main transformer and to the UAT. [8.3-8]

8.3.1.1.2.3 Main Transformer

The main transformer steps the 18-kV generator voltage up to 345 kV for distribution to the CECo, MEC, and the ITC Midwest transmission systems. The main transformer windings are delta connected on the 18-kV side and wye connected with a neutral center tap ground on the 345-kV side. The transformer rating is given in Table 8.3-1. [8.3-9]

8.3.1.1.2.4 Unit Auxiliary Transformer

The UAT steps the 18-kV generator voltage down to 4160 V for use with the station auxiliaries. The transformer windings are delta connected on the 18-kV side and wye connected with a neutral center tap ground on the 4160-V side. The transformer rating is given in Table 8.3-1. [8.3-10]

8.3.1.2 4160-V System

The 4160-V system provides ac power to station auxiliaries required for plant operation.

The electrical loads for each unit are split between two systems of three 4160-V auxiliary buses each. The engineered safety features equipment associated with each system can be powered by the DGs. For Unit 1, one system includes buses 11, 13, and 13-1; the other includes buses 12, 14, and 14-1. Buses 13 and 13-1 are designated as Division I and buses 14 and 14-1 are designated as Division II. Each bus has its own feed breakers. If a short circuit occurs on one of the buses, that bus is isolated by the opening of its breaker, thus leaving the bus on the other system and its required equipment available for use. A similar system is provided for Unit 2. [8.3-11]

Buses 11 and 12 provide power to the feedwater pumps and the reactor recirculation pumps. Buses 13, 14, 13-1, and 14-1 supply power to all other plant services. The general design requirement is to supply duplicate services from different buses. Failure of any one of the four main buses (11, 12, 13, or 14) will still permit the station to operate at reduced output. This also applies to the Unit 2 system.

The switchgear for the 4160-V bus is metal-clad indoor type. Circuit breakers are three-pole, electrically-operated, with a 125-Vdc , stored-energy closing mechanism. Also included in the system are devices such as bus undervoltage detection relays, GE Type IAV; auxiliary relays for contact multiplication, GE Type HFA, HGA, and HEA; timing relays, GE Type CR 2820; and GE Type SB-1 and SBM control switches. Devices such as these are used in the system for control, sensing, and automatic operations. [8.3-12]

8.3.1.2.1 System Description

Normal power is supplied to the 4160-V system from the main generator 18-kV bus through a UAT and from the 345-kV system through the RAT. [8.3-13]

During normal operation, part of the station auxiliary load is supplied from the UAT and the other part from the RAT. When the generator is not operating, as during startup, shutdown, or unit trip, the loads fed from the UAT are transferred to the RAT. The unit's RAT is the primary offsite source to the essential service buses. The RAT of the other unit provides the second offsite source through a bus tie provided between corresponding essential service buses of the two units.

There is a crosstie connection between buses 13-1 (14-1) and 23-1 (24-1), which may be used to supply power from one unit to the other under abnormal conditions. Bus 31 which is shared between the units, provides power for the safe shutdown makeup pump and its auxiliaries. The normal power supply to bus 31 is bus 14-1, and the alternate is bus 24-1. This is a manual transfer.

Upon a loss of normal source voltage, the 4160-V buses will automatically transfer to their alternate power source, providing that the alternate source is energized and that there is no fault on the alternate bus. This transfer occurs fast enough to preclude load trip due to undervoltage. The only exception is that the UAT feed breakers to the ESS buses will not attempt a fast transfer if there is a LOCA signal present. This transfer is prevented with a LOCA signal present to ensure the ESS loads are not subjected to three start attempts in the case of a concurrent LOCA and a loss of the RAT due to an open phase event on the supply to the RAT.

A 3-hour rated, seismic Class I fire barrier is installed between the 4160-V switchgear 13-1 and 14-1 to prevent fire from spreading from one switchgear area to the other for Unit 1. A similar barrier is also installed between switchgear 23-1 and 24-1 for Unit 2. [8.3-14]

8.3.1.2.2 Systems Components

The major components of the 4160-V system are the UAT, the RAT, the 4160-V switchgear, and the circuit breakers. The UAT is described in Section 8.3.1.1.2.4. [8.3-15]

8.3.1.2.2.1. Reserve Auxiliary Transformer

The RAT (TR-12 for Unit 1 and TR-22 for Unit 2) steps switchyard voltage from 345 kV down to 4160 V for use with station auxiliary loads. The rating of the transformer is given in Table 8.3-1. TR 12 and TR 22 are 345-4.3-4.3 kV three phase transformers with an automatic load tap changer (LTC) on the 4.3 kV X-winding. The LTCs provide a range of +25% to –5% of the rated voltage in 32 steps, each step being approximately 0.938% of rated voltage. The LTC may be operated manually or in the automatic (voltage regulating) mode.

The automatic LTC has both a primary and backup controller. The backup controller prevents the primary unit from running the secondary side voltage outside the desired upper and lower limits in the event of a primary controller failure.

Automatic operation of the LTC was evaluated by the NRC under License Amendments 232 and 228 for Units 1 and 2 respectively. The evaluation determined that the potential failure modes of the LTC are not likely to cause a common mode failure of the safety related equipment powered from TR 12 or TR 22. A failure in which the LTC rapidly increases or decreases transformer output voltage is not likely, since both the primary and backup controllers would have to fail. A failure of the LTC to respond to changing transmission system voltage would occur slowly and can be mitigated by operator action.

The RATs have protective relaying that includes phase and neutral overcurrent, current differential, sudden pressure, and open phase detection.

8.3.1.2.2.2 4160-V Switchgear

The 4160-V switchgear provides a means of enclosing the bus work, breakers, and relays associated with the 4160-V system. The switchgear for the 4160-V buses is located in the turbine building and the Station Blackout Building. [8.3-16]

8.3.1.2.2.3 Circuit Breakers

Circuit breakers provide a method of isolating loads and power supplies from the 4160-V buses. The breakers are supplied in three current ratings: 1200A, 2000A, and 3000A.

8.3.1.3 13.8-kV System

Power to non-plant facilities is supplied by transformers TR-81 and TR-82. These are 345-kV to 13.8-kV transformers connected to the 345-kV ring bus. The 13.8-kV distribution system consists of bus work, disconnects, breakers, and transformers necessary to supply non-plant facility loads, including normal power to the SBO DG building. [8.3-17]

8.3.1.4 480-V System

Power is supplied from 4160-V buses 13, 14, 13-1, and 14-1 to the 480-V buses through nine separate transformers including the well water pumphouse and gatehouse transformers. The 480-V buses supply power to electrically operated auxiliaries. The 480-V buses are the indoor load center type which in addition to supplying power directly to the 480-V motor loads also supply the transformers used in stepping down the voltage to 208/120 V for lighting, instrumentation, and small plant service loads. The power for equipment vital to safe plant shutdown under accident conditions is supplied by 4160-V buses 13-1 and 14-1 and by 480-V buses 18 and 19. A similar arrangement exists for Unit 2. [8.3-18]

Transformers and switchgear for the 480-V buses are located in the turbine building and reactor building. The 480-V MCCs are located in the turbine, reactor, radwaste, crib and boiler house buildings. Switchgear for each load center is in self-supporting metal-clad sections with continuous main buses which have draw-out units that are replaceable under live bus conditions. Circuit breakers are either electrically operated from the 125-V station battery or manually operated. [8.3-19]

8.3.1.4.1 System Description

The 480-V system consists of seven buses for each unit and one shared bus (30). These buses supply large 480-V motors (such as fans) and 480-V MCCs for the control of small 480-V motors (such as valve motors). Each 480-V bus is fed from a 4160-V bus via a 4160-480V transformer. Each of these transformers is an oil/air (OA) type transformer, which relies on natural convection of both the oil and the air for cooling. In addition, Unit 1 also supplies power to gatehouse and well water pumphouse 480-V loads via 4160-480-V transformers. [8.3-20]

A. Bus 13 (23) feeds buses 1A and 15 (2A and 25).

B. Bus 14 (24) feeds buses 16 and 17 (26 and 27) and transformer for well water pump number 5 (Unit 2).

C. Bus 13-1 (23-1) feeds buses 10 and 18 (20 and 28) and the well water pumphouse transformer (Unit 1) for well water pump Number 1.

D. Bus 14-1 (24-1) feeds bus 19 (29), bus 31, and the gatehouse auxiliary transformer (Unit 1).

E. Bus 31 feeds MCC 30.

Buses 18 and 19 (28 and 29) are 480-V essential service (ESS) buses. These buses can be powered by the DGs via the 4160-V ESS buses.

Motor control centers are designated by the feeding bus number followed by a sequential number (e.g., MCC 18-1 is fed by bus 18; MCC 16/26-1 can be fed from either bus 16 or 26).

Manual crossties exist between buses 15 and 16, buses 15 and 17, and buses 18 and 19 in order to supply power to one of these buses in the event its normal supply is lost.

8.3.1.5 120-V System

The main function of the 120-V system is to provide a reliable source of 120-V, 60 Hertz, single-phase power for plant controls and instrumentation. This system is divided into three different subsystems:

1. 120-V reactor protection system (RPS),
2. 120-V instrument bus system, and
3. 120-V essential service system (ESS).

8.3.1.5.1 120-V Reactor Protection System

The RPS consists of two buses: A and B. Each 120-V RPS bus is supplied by a motor-generator (M-G) set, which is fed from 480-V MCC 18-2 (28-2) and 19-2 (29-2). These MCCs are supplied from essential service 480-V buses 18 (28) and 19 (29). A reserve supply to each RPS bus exists from 480-V MCC 15-2 (25-2). This reserve supply is interlocked with the normal supply by use of a keylock switch to prevent simultaneous feed from both sources. The detailed description of this system is provided in Section 7.2. [8.3-21]

8.3.1.5.2 120-V Instrument Bus System

The instrument bus system supplies 120-V power for various control circuits, relays, solenoids, and instruments. The normal power supply to the instrument bus is MCC 18-2 (28-2), the alternate power supply is MCC 15-2 (25-2). On loss of the normal power supply, an automatic bus transfer (ABT) switches power to MCC 15-2 and transfers it back upon restoration of normal power (normal seeking ABT). The instrument bus distribution panel is located in the auxiliary electric room (Panel 901(2)-50). Bus voltage indication is available at the bus cabinet in this room. [8.3-22]

8.3.1.5.3 120-V Essential Service System and Uninterruptible Power Supply

The Quad Cities Essential Service System (ESS) Bus is a 120/240 VAC distribution center supplying loads important to the unit operation as well as a small number of safety-related components. The ESS bus is normally supplied by an Uninterruptable Power Supply (UPS) that provides noise free, voltage regulated and frequency controlled "clean" power to enhance the reliability of connected components. The UPS was installed in 1982 in response to reliability concerns with the motor generator sets originally installed. The UPS was procured and installed as non-safety related (classified "reliability related").[8.3-23]

Power to the UPS is supplied, in order of preference, by bus 18 (28), 250 V battery via 250-Vdc MCC 1(2), and bus 17 (26). The 120 VAC output of the UPS is connected to a 50 kVA, 120:120/240 VAC step-up transformer which feeds the ESS Bus. The ESS Bus is isolated from the UPS by a circuit breaker and an Automatic Switch Company (ASCO) Automatic Bus Transfer (ABT) switch. This method of isolation meets the applicable industry standard, IEEE 279-71. Employing redundant and diverse power supplies mitigates single failure events. The credited post-accident Emergency Diesel Generator (EDG) supplied feed to the ESS Bus is from safety-related MCC 18(28)-2 through a 37 kVA transformer. If the UPS fails, the safety-related ABT will automatically transfer to the feed from MCC 18(28)-2.

The UPS and the essential service distribution panels are located in the auxiliary electric room (UPS: 901(2)-63, ESS: 901(2)-49).

8.3.1.5.4 Computer Bus

The computer bus supplies power to the process computers and the fire alarm system main panel. This bus is normally fed from 480-V bus 17 through an uninterruptible power supply. The alternate supply is from 480-V bus 26. The alternate dc power supply is from a 250-V UPS battery. [8.3-24]

8.3.1.6 Standby Emergency Diesel Generator System

The station is provided with sufficient and independent power sources to assure safe reactor shutdown under emergency conditions (worst case) on total loss of all offsite power (LOOP) concurrent with a design basis accident. This capability is attained by use of an emergency DG ac power source and by the station battery dc power systems. The dc power system is discussed in Section 8.3.2. Additional standby DGs have been installed in order to meet the requirements of 10 CFR 50.63, Station Blackout Rule. The SBO DGs are discussed in Section 8.3.1.9. [8.3-25]

The DG system provides emergency source of ac power in the event all normal offsite power becomes unavailable. The system consists of three DGs: 1, 2, and 1/2, a shared DG. One DG is capable of providing the necessary power for a safe unit shutdown during a LOOP with or without an accident occurring simultaneously. Refer to Section 6.3.3.2.9 for the design basis for the duration of the loss of offsite power.

8.3.1.6.1 Components

The three DGs are physically separated inside the plant. DG 1 (Unit 1) and DG 2 (Unit 2) are located in separate concrete compartments at opposite ends of the turbine building at elevation 595 feet. Diesel generator 1/2, the "swing" DG, is located in a concrete compartment on the east wall beyond the reactor building (see General Arrangement Drawing M-5). The fuel supply for each diesel is discussed in Section 9.5.4. [8.3-26]

Each DG provides power to the essential service 4160-V switchgear, is rated at 3250 kVA, 0.8 power factor, and has a continuous rating of 2600 kW. The continuous rating is defined as that continuous load which will permit supplier guaranteed operation at a 95% reliability with a periodic maintenance period. Additional ratings are listed in Table 8.3-1. [8.3-27]

Motive power for the standby DGs is supplied by V-20, turbocharged, fuel-injected diesel engines. A Woodward UG-8 engine governor is used on each diesel and is set to maintain a constant 900 rpm. Fuel flow to the cylinders is controlled by movement of the fuel racks. Increasing the fuel flow allows the engine to maintain a constant speed as it assumes a greater load. Refer to Section 9.5.4 for a description of the fuel oil storage and transfer system. [8.3-28]

The DG system is designed to start in the automatic mode within 13 seconds and to accept full load within 40 seconds. This rapid start capability is consistent with the core cooling requirements under postulated accident conditions. The starting system is pneumatic and uses dual air starting motors. The system also has a manual start mode and allows for periodic starting and synchronizing with offsite auxiliary power. This configuration allows readiness testing without interrupting normal plant service. [8.3-29]

Control and generator field flashing power is supplied from the 125-Vdc station battery system.

Each diesel generator is provided with instrumentation, alarms, and protective trip functions. An automatic trip of the diesel may occur for any of the following reasons: [8.3-30]

A. Engine overspeed,

B. High engine temperature,

C. Low cooling water pressure,

D. High crankcase pressure,

E. Low main bearing lube oil pressure,

F. Differential overcurrent.

In the manual start mode (from the control room), all of the trips are functional; however, in the automatic emergency mode, all but the differential overcurrent and overspeed trips are disabled. An overspeed trip will stop fuel injection and shut down the diesel. The control room will receive a "D/G Trouble" alarm when the diesel is tripped for any of the previously listed reasons. To restart the diesel after a trip, the actuated trip relay(s) must first be reset at the engine control panel.

Start failure logic exists to prevent restarting of the EDG following a failure of the engine to reach 200 rpm following a start signal, either manual or automatic. The control room will also receive a "start failure" alarm. This logic is always operational.

For a discussion of the diesel generator cooling water system, see Section 9.5.5. For diesel fuel oil storage and transfer, see Section 9.5.4. For starting air, see Section 9.5.6. For diesel generator lubrication, see Section 9.5.7. For the diesel generator combustion air intake and exhaust, see Section 9.5.8. For the diesel generator room ventilation system, see Section 9.4.5.

8.3.1.6.2 System Arrangement

The DG ac power system is shown on Figure 8.3-1. As noted on this figure, the system is a "split bus" arrangement. Diesel generator 1 provides power for one half of the Unit 1 ECCS equipment. Diesel generator 2 provides an equivalent function for Unit 2. The other half of the ECCS equipment is powered from the swing diesel, DG 1/2. This DG provides power in one of two manners, depending upon the plant operating status. First, if a LOOP occurs and no accident signal is present from either unit, DG 1/2 is automatically connected to bus 13-1 (Unit 1), or 23-1 (Unit 2), depending on which unit loses power first. Second, if a LOOP occurs with a loss of coolant accident (LOCA) signal, DG 1/2 is automatically connected to the unit having the accident signal and is disconnected from the other unit. [8.3-31]

There are a number of other manual capabilities within the system. For example, DG 1 can power the Unit 2 main 4160-V ESS bus, if desired, by manually closing two circuit breakers. Also, the DG system can backfeed to the main unit 4160-V auxiliary buses from the 4160-V ESS buses by manually closing two circuit breakers. However, such manual operations are possible only under certain specific conditions because interlock devices are installed to protect against possible fault conditions. For example, connecting DG 1 to Unit 2 4160-V ESS bus cannot be accomplished if DG 2 is already connected to that bus. Such flexibility is an operational convenience designed and controlled such that safety is not jeopardized.

8.3.1.6.3 System Loads

The system loads are divided into two major categories: LOOP and LOOP plus an accident. Both of these categories are subdivided into automatically connected loads and manually connected loads. Table 8.3-2 summarizes the major DG loading for both automatic and manual operation on LOOP only. Table 8.3-3 summarizes similar major DG loading for the LOOP plus accident case. These tables list the equipment power requirements that are assumed to occur simultaneously at rated conditions.

Automatic primary loads such as the main ECCS pumps are sequenced to assure sufficient power is available during these transient conditions. Sequences depend on specific operating conditions and can be obtained from the functional control diagrams provided in Section 6.3, and from the ECCS electrical loading sequence.

8.3.1.6.4 Primary Operational Characteristics

Under normal operating conditions the ECCS systems of Unit 1 are powered from buses 13-1 and 14-1 (refer to Figure 8.3-1). These buses receive power from 4160-V buses 13 and 14 which are fed from the UAT and the normal offsite ac power sources via the RAT. In the event of loss of these power sources, buses 13-1 and 14-1 are automatically disconnected from buses 13 and 14 and connected to the respective diesel generators DG 1/2 and DG 1. Simultaneous with the interruption of power from 13 and 14, all nonessential loads on the buses supplied by 13-1 and 14-1 are tripped from the buses. Similarly, the major loads on the main 4160-V auxiliary buses 13 and 14 are tripped. This general sequence of events occurs in a similar manner on Unit 2.

Six basic signals will automatically start DG 1. These signals are: undervoltage on main 4160-V bus 14, undervoltage on 4160-V bus 14-1, the main feed breaker between 14-1 and 14 open, both feeds to bus 14 open (a 1 second time delay is incorporated into this signal to prevent the inadvertent start of the EDG during a successful automatic transfer of the Main and Reserve Feed breakers at bus 14), degraded voltage on 4160-V Bus 14-1, or a LOCA signal (high drywell pressure or low-low water level) on Unit 1. Diesel Generator 2 in Unit 2 is started in an identical manner except that the bus and accident signals are associated with Unit 2. The same signals, on buses 13 (23) or 13-1 (23-1), start DG 1/2. [8.3-31a]

A series of permissives must be met in order to connect the DG power to the ESS 4160-V buses. The permissives are met when:

A. The main feed breaker between buses 14 and 14-1 (typical) is open;

B. The crosstie breaker between buses 14-1 and 24-1 is open;

C. There is no fault on bus 14-1;

D. There has been an undervoltage on bus 14-1 for 2 seconds or longer;

E. There is no fault on DG 1;

F. DG 1 is at rated speed; and

G. DG 1 is at rated voltage.

When these permissives are met, the breaker between the DG 1 and the 4160-V bus 14-1 closes. The breaker automatically opens on a DG 1 generator differential relay operation or when DG 1 is tripped from an overspeed condition. The Unit 2 system is similar. The DG 1/2 connection to the two units is the same except that an additional permissive is provided that allows the breaker to close only if a LOCA signal from the opposite unit is not present. If such a signal is present, e.g., on the Unit 2 side, then the DG 1/2 breaker to Unit 1 bus 13-1 is automatically opened and the breaker to Unit 2 bus 23-1 is closed. [8.3-32]

Other special features of the system can be seen from the schematic diagram, Figure 8.3-1. The 480-V MCC 18/19-5 is made up of two MCCs whose buses are connected with a copper link to form one continuous bus. At the point of connection there is a steel barrier which separates the two MCCs. The purpose of this common bus is to provide a dual source of power to the residual heat removal (RHR) and recirculation valves for operation in the low pressure coolant injection (LPCI) mode. The MCC 18/19-5 is normally supplied from DG 1 through 4160-V bus 14-1, transformer TR-19 and bus 19 during a LOOP with or without an accident signal. Should the DG 1 power source fail, the breaker and contactor feeding MCC 18/19-5 from bus 19 will open automatically, the breaker and contactor feeding MCC 18/19-5 from bus 18 will close automatically restoring power to these buses from DG 1/2 through bus 13-1, transformer 18, and bus 18. The source breakers to MCC 18/19-5 are interlocked such that DG 1 and DG 1/2 are isolated from each other at all times. A tie exists between 480-V buses 18 and 19. The tie is normally open through two breakers which are interlocked in such a manner that they cannot be closed unless one of the two buses (18 or 19) is disconnected from its normal DG source. The purpose of this tie is to provide operational flexibility so that in the event of a LOOP and failure of one of the two DGs, the entire drywell cooling system can be made available manually. Bus 14 can also be backfed from bus 14-1 manually (when in this backfeed configuration, having the main and reserve feed breakers to Bus 14 open provides a seal-in to the DG Auto Start Relay (ASR)). Again, interlocks or synchronization features of the system are incorporated to assure that when such a configuration is used, no fault or occurrence on one DG system will cause loss of the other DG system. The purpose of this backfeed capability is to provide power to certain long duration equipment, such as containment cooling water pumps, that may be needed for a significant period of time (hours) after a postulated accident, and to provide operating flexibility within the plant. To have such equipment normally powered by the emergency bus tends to reduce the reliability of the systems that are needed immediately following a postulated accident. These capabilities were discussed in relation to DG 1 system; DG 2 and DG 1/2 systems are similar. [8.3-33]

Design changes were implemented that supplement the previously described automatic transfer logic to initiate an automatic transfer based upon voltage and frequency abnormalities when the 480-Vac swing MCC 18/19-5 (28/29-5) is supplied from DG 1 (2). This is accomplished with protective relays monitoring and generating a transfer signal based upon overvoltage, undervoltage, overfrequency and underfrequency conditions. This precludes a particular failure of the unit DG voltage regulator during a LOCA concurrent with a LOOP event which could lead to a loss of all but one loop of the low pressure ECCS. [8.3-34]

Circuitry exists to permit the transfer of the RHR swing MCC 18/19-5 (28/29-5) to its alternate source, despite a postulated loss of the associated dc control power. As a result, the reliability of the power source to the RHR injection valves is enhanced. [8.3-35]

Individual component failures within the swing MCC's control logic could prevent transfer to the alternate source upon loss of the normal source or could disconnect both power feeds resulting in the loss of power to the injection valves of the LPCI mode of RHR system fed from this MCC. Alternately, individual component failures in the swing MCC's control logic could cause an inappropriate transfer to alternate, which, upon future loss of this alternate, would also disable the same injection valves. These failure modes still exist in the modified configuration. [8.3-36]

The LPCI Swing Bus 18/19-5 (28/29-5) design does not meet the requirements of Generic Design Criteria 17 of Appendix A to 10 CFR Part 50. Under Regulatory Guide 1.6 for class 1E electric power systems, a swing bus concept does not satisfy the single failure criterion. This design can potentially cause redundant emergency diesel generators to be paralleled resulting in a loss of redundant emergency power sources. The Nuclear Regulatory Commission acknowledged and approved of the LPCI swing bus design weakness in the Quad Cities Safety Evaluation Report, dated August 25, 1971. The design was reexamined and again found acceptable in NUREG-0138 issued November 1976. The Commission accepted the design principally because the ECCS acceptance criteria can be met without any LPCI function. In addition the swing bus has loads only associated with LPCI functions, thus confining single failure within the bus. On this basis the commission granted an exemption from GDC 17 of Appendix A to 10CFR Part 50 on December 7, 1990.

Second-level undervoltage protection which protects the ESS equipment from sustained degraded voltage of the offsite power system is discussed in Section 8.3.1.8. [8.3-37]

The degraded voltage and the undervoltage allowable values are listed in the plant technical specifications. The degraded voltage signal must be present for a specified time period before a DG start signal is given. The allowable values for the time delays associated with the degraded voltage function are also specified in the Technical Specifications. An evaluation of the effects of degraded voltage on the plant is discussed in subsection 8.3.1.8. [8.3-38]

Design changes were implemented that addressed concerns mentioned in Institute of Nuclear Power Operations (INPO) SOER 81-10. On an ECCS initiation signal, the DG is designed to start but not pick up its bus if the bus is live. However, if a LOOP occurred after starting ECCS pumps, the DG breaker would have immediately closed on to the bus with the pumps running. The breaker closure would not have been synchronous and could have damaged the pumps or the DG. To protect against this, a time-delay relay has been added with a setpoint such that a minimum 2-second delay will occur, and the setpoint will not interfere with the required starting time of the diesel generator. This will allow the bus voltage to decay so that the DG will close on to a virtually dead bus. [8.3-39]

8.3.1.6.5 Tests and Inspections

Since the DGs are utilized as standby units, readiness is of prime importance. Readiness can best be demonstrated by periodic testing, which insofar as practical, simulates actual emergency conditions. The testing program is designed to test the ability to start the system as well as to run under load long enough to bring all components of the system into equilibrium. This assures that cooling and lubrication are adequate for extended periods of operation. Full functional tests of the automatic circuitry are conducted on a periodic basis to demonstrate proper operation. [8.3-40]

8.3.1.7 Electrical Cable Installation

Cables are routed in a tray system with instrument cables in pans separate from power and control cables so that low level signals are not affected by higher voltages or switching functions. Cable trays may be open (ladder) or solid bottom type trays. Reactor protection system cables are maintained in a conduit system and are not intermixed with other power and control cables. Reactor protection system cables have channel separation requirements which are maintained by the conduit system. Nonvital cables are not mixed with RPS cables. [8.3-41]

Penetrations of the primary containment for electrical cables are made primarily in one horizontal plane. Division separation requirements are maintained by entering the containment from opposite sides. If more than two divisions are required, additional separation is maintained by alternating penetrations carrying redundant cables.

Cable pans for different divisions are spaced at least 3 feet apart horizontally or 5 feet apart vertically where possible in hazardous areas. The original design utilized the solid bottom trays when vertical stacking or tray crossing occurred. In non-hazardous areas, such as the cable spreading room, pans for different divisions may be spaced one foot apart horizontally or three feet apart vertically per IEEE 384-1981 for newer designs. Where separation requirements cannot be met, qualified fire barriers are installed. For 10 CFR 50 Appendix R conformance and exemption reports relating to cable installation refer to the Quad Cities Fire Protection Reports.

The current carrying capacity of electrical cables is limited by the temperature rating of the cable insulation. A computer program is utilized to monitor cable ampacity and identify potentially overloaded cable routing points. Cables at the potentially overloaded routing points are further evaluated to determine if cable ampacity deration is required.

Cable insulation is generally butyl rubber with a polyvinyl chloride (PVC) jacket, except in the containment area for which cross-linked polyethylene with a PVC jacket is specified.

Fire stops are installed in cable pan runs wherever pan systems pass through walls or floor openings. Fire stops and ventilation stops are placed in all conduit sleeves entering or leaving major ventilated areas. Cable tunnels have separate sprinkler systems. Cable spreading rooms are monitored with smoke detectors and alarms.

Engineered safety features cables and their associated pan systems are marked by color code for their respective division assignments. All division pans are identified wherever they pass through a wall on both sides of the wall.

Process instrumentation inside the drywell is generally located so that redundant elements are in opposite areas. The components on which the process elements are mounted or connected are placed as close to 180° apart as possible. Redundant sensing wires and cables are brought out through separate penetrations.

8.3.1.8 Analysis of Station Voltages

This section provides historical data; refer to the most recent version of the Electrical Load Monitoring System (ELMS) data base.

The effect of a degraded grid voltage on the station electrical distribution system and its associated loads has been analyzed. Unit 1 and 2 were evaluated separately by assuming a voltage level of 3845 volts present at 4160-V buses (13-1 and 14-1 or 23-1 and 24-1). The unit being analyzed was also assumed to have experienced a concurrent Loss of Cooling Accident (LOCA). This case represents the auxiliary system loading which results in the worst case voltage at the 480-V level. Specific bus loading used in the calculations was determined by using the current Electrical Load Monitoring System (ELMs) data file for the degraded voltage/LOCA scenario. The results of the calculations show that most continuous loads required during a LOCA will have a running terminal voltage ≥ 90% of their rated voltage. Minimum voltage is limited to 90% of equipment rated voltage per the National Electric Manufacturers Association (NEMA) Standard. Loads which are calculated to have < 90% of their rated voltage have separate calculations justifying the lower voltage. Loading on the 480-V and 4160-V buses and the running voltage for loads are contained in the ELMS files. [8.3-42]

To protect the ESS equipment from the effects of a degraded grid condition, another set of undervoltage relays have been added to 4160-V buses 13-1, 14-1, 23-1, and 24-1. Each set is comprised of two solid-state undervoltage relays that have an inherent time delay of 7 seconds, arranged in a two-out-of-two logic scheme, with associated auxiliary relays and a timer added to the undervoltage logic circuitry. The nominal dropout (critical voltage) of the second-level protection relays is 3845 volts with a time delay of 5 minutes in the logic circuit. Calculations have been prepared to determine the actual setpoint for the relays. The calculations show that the relays must be set at a value higher than 3845 volts to account for instrumentation uncertainties. Should the two undervoltage relays remain tripped for 5 minutes, or if a LOCA signal occurs during the 5 minute period, the undervoltage condition is annunciated in the control room, incoming line breakers are tripped, load-shedding is initiated, and the DG is started and its breaker closed when the voltage and frequency from the DG are satisfactory. [8.3-43]

The time delay of 5 minutes was selected to permit operator action to improve the voltage levels. There is no induced time delay for undervoltage protection should an accident signal occur, since the time delay is defeated immediately should a LOCA occur. The bus will be ready to transfer to DG power before the diesel is up to speed. Load shedding is blocked when the DG supply breaker is closed and automatically reinstated once the breaker opens. The minimum inherent time delay of the degraded voltage relays is long enough to override any short inconsequential grid disturbances. The circuits associated with the undervoltage relays meet the applicable requirements of IEEE Standard 279-1971.

The allowable values for the degraded voltage and associated time delay settings are specified in the Technical Specifications.

Bus voltage droop during starting of various loads has been evaluated using the same assumptions used for the running voltage calculations. The worst case condition results from starting a 9000-hp reactor feed pump which causes voltage on bus 11 or 12 to drop to 3086 V or 77.2% of the 4-kV rated motor voltage. The starting voltage for the other 4-kV motors is above 80% of motor rated voltage. The total horsepower of all essential service motors simultaneously starting through one RAT winding in the event of a LOCA is approximately 400hp. Bus voltages during motor starting conditions are shown in Table 8.3-8. [8.3-44]

To provide adequate torque for starting safety-related motors and to prevent contactors from dropping out at 480-V buses, the minimum starting voltage for safety-related low-voltage motors shall be 90% of motor rated voltage; otherwise, lower starting voltage shall be supported by an analysis to justify the starting at lower voltage. The minimum voltage at which transfer of load to the buses occurs due to degraded voltage is 3045 V or 76.0% of 4 kV. Since the minimum expected bus voltage during normal or motor starting operation, 3616 V, is well above the relay setting, transfer to the onsite power supply should not occur. The undervoltage relays incorporate sufficient time delay so that short circuits can be cleared without undervoltage relay operation.

Voltages at the 480-V buses have been included in the evaluations. With the unit substations set at 4055 V (-2.5%) tap, maximum voltages are satisfactory. This 2.5% boost can result in maximum voltages in excess of 110% of motor rated voltages if the transformer is lightly loaded and the switchyard voltage is at its maximum value. The no-load voltage on 480-V buses 19 and 28 was calculated as 518 V which is 108% of the nominal 480-V bus voltage and 112.6% of the 460-V motor ratings. This is slightly higher than the 110% NEMA Standard limit. No load voltages for selected buses are shown in Table 8.3-8.

However, tests have shown that safety loads will not be subjected to unacceptable overvoltages. As soon as the buses are loaded even slightly, there is enough voltage drop in the supply transformers and the associated cable to the equipment that the expected voltages at the equipment terminals will be very close to 110%. [8.3-45]

The minimum voltage at the 480-V switchgear occurs on bus 28 at full load assuming the switchyard voltage is 333 kV and the short circuit level is 5195 MVA. These conditions result in a voltage of 435 V or 94.6% of the 460-V motor rated voltage. The minimum voltage at the switchgear allows for a 4.6% drop in cable between the 480-V switchgear and the 460-V motor. A 3.2% drop in voltage has been calculated for a cable between the 480-V switchgear and the 460-V motor terminal. This cable was expected to have the maximum voltage drop. Voltage under full load conditions is shown in Table 8.3-8. [8.3-46]

Design modifications were implemented to automatically shed sixteen non-safety related loads on high drywell pressure or low-low reactor water level signals with or without offsite power available. These loads were shed to improve voltage regulation on 480V ESS buses 18 (28) and 19 (29) for degraded voltage conditions that could prevent starting of safety related motor loads during a LOCA design basis accident when offsite power is available. Two trip bypass control circuits (one per division) were installed in the main control room to provide manual restart capability for various loads which are shed.

8.3.1.9 Station Blackout Diesel Generator System

In response to the Station Blackout (SBO) Rule, ComEd committed to install a "fully-capable" alternate AC (AAC) system. This system would consist of a standby diesel generator, available within one hour of the onset of an SBO event, controllable from the main control room, and connectable to all safety buses (Bus 13-1 and 14-1). The "fully-capable" designation and the fact that the SBO diesels are larger than the emergency DGs (per unit basis), allows: (1) all diesels (SBO DGs and emergency DGs) to be maintained at a reduced reliability factor of 0.95 and (2) a reduction of demonstrable AC-independent coping ability from four hours to one hour. The SBO DG safe shutdown function is described in the Safe Shutdown Report (FPR Volume 2). The following function and component descriptions are for the Unit 1 system. Configuration and capability of the Unit 2 system is similar. [8.3-47]

Design of the SBO system was based on Appendix B of NUMARC 87-00, which was developed as an NRC-approved guideline to utilities to determine station-specific requirements for meeting the station blackout rule. The design, installation, testing and maintenance of the SBO system and components are in compliance with the requirements of Regulatory Guide 1.155, "Station Blackout." Compliance with the Regulatory Guide is accomplished through approved plant procedures and other administrative controls.

The SBO system is a non-class 1E, independent source of additional on-site emergency AC power. The system consists of two diesel-driven generator sets, each having a continuous rating of 4350 kW at 4160 V at a power factor of 0.8. The 2000-hour/year rating is 4785 kW. Each generator is connectable, but not normally connected, to the safe shutdown equipment on one nuclear unit, but can also be connected to the opposite unit via the safety-related 4kV cross-ties. The SBO DGs must be manually started and manually connected to the appropriate safe shutdown loads. The start and load functions of the SBO DG can be performed from the main control room.

8.3.1.9.1 Primary Operational Characteristics

The SBO DG is designed to be remotely or locally started in the emergency mode under conditions of total or partial loss of offsite power. In the emergency mode the engine will immediately accelerate to rated speed and almost all trips are bypassed. Dead bus connections can be made to allow the SBO DGs to provide power to safe shutdown plant loads. Emergency operation is designed to utilize the programmable logic controller (PLC). If a failure is detected in the PLC, the DG can still be started and controlled locally in the PLC Bypass mode. This is reserved for emergency operation only because the emergency start pushbutton must be depressed which provides for a fast start and bypasses trips. The trips which are not bypassed during emergency conditions, are:

A. Engine overspeed
B. Generator ground fault
C. Generator differential

The generator trips require resetting a lockout relay at the SBO switchgear and the overspeed trip requires resetting an engine latch.

Prior to starting the engines for surveillance tests (i.e. non-emergency conditions), the lube oil valves can be manually configured to provide prelubrication of the engine bearings and rocker arm assemblies while the engine is barred over one revolution. This reduces the rate of engine wear. The engines can then be remotely started in the normal mode. This mode operates the engine for 5 minutes at idle speed prior to going to rated speed and all trips are enabled. Synchronized breaker closings connect the generator set to the plant safety buses and off-site power for loading. A local normal (non-emergency) start is also possible. Synchronized breaker closings must be performed remotely. In addition to the trips enabled in the emergency mode, the following trips are enabled in the normal mode:

A. Engine A/B Lube Oil Pressure LO-LO
B. Engine A/B Jacket Water Pressure LO
C. Engine A/B Jacket Water Temperature HI-HI

D. Engine A/B Crankcase Pressure HI
E. Generator Overcurrent
F. Generator Negative Sequence
G. Generator Loss of Field
H. Generator Neutral Overvoltage
I. Generator Reverse Power

A local or remote emergency stop can be performed which will immediately stop the engines and trip the output breaker. A local or remote normal stop can also be performed. If the diesel generator is in the normal mode, the generator feed breaker will trip and the engine will run at idle speed for a cooldown period before stopping.

A four-position control switch ("LOCKOUT/REMOTE/LOCAL/PLC BYPASS") at panel 2201-105 controls some of the DG functions. In LOCKOUT position, the engine starting air solenoids are prevented from being energized. In conjunction with isolating the starting air valves and racking out the generator output breaker, this position is used for taking the DG out-of-service. In REMOTE position, normal starting and stopping of the DG can only be done from the main control room. In LOCAL position, normal starting and stopping can only be done from the SBO Building. Emergency starting or stopping can be done either remotely or locally regardless of the switch position in LOCAL or REMOTE. In PLC BYPASS position, critical engine controls (starting, stopping, non-bypassed trips) which otherwise are provided by the PLC, are bypassed in favor of hard-wired control circuitry. Only a local emergency start is possible and the start pushbutton must be depressed continually until the starters disengage automatically above 200 rpm. Control of generator loading via voltage and speed controls can be done remotely or locally regardless of the REMOTE/LOCAL switch position.

8.3.1.9.2 System Arrangement

Under conditions of total or partial loss of offsite power (i.e., emergency conditions), the SBO DG can be remotely or locally started in the emergency mode in which the engine will immediately accelerate to rated speed and all trips except overspeed, generator ground fault, and generator differential are bypassed. Dead bus connections can be made to allow the SBO DGs to provide power to safe shutdown plant loads. Emergency operation is designed to utilize the programmable logic controller (PLC). If a failure is detected in the PLC, the generator set can still be started and controlled locally in the PLC bypass mode; however, this is reserved for emergency operation only because the emergency start pushbutton must be depressed which provides for a fast start and bypassed trips.

The configuration of the SBO 4160-V distribution system provides the capability of the Unit 1 SBO DG set to be connectable, but not normally connected, to either of the 4160-V ECC buses. Figure 8.3-1 shows that the Unit 1 SBO DG feeds 4160-V SBO Bus 61 which then connects to either 4160-V ECC buses. These connections will be isolatable via a two breaker system, that is, one safety-related and one non-safety-related breaker in each line-up. If conditions require it, the safety-related cross-tie between Bus 13-1 and 23-1 (14-1 and 24-1) can be utilized so that the Unit 1 SBO DG can supply power to Unit 2 loads.

8.3.1.9.3 System Loads

The Unit 1 SBO DG generator rating is 4350 kW continuous, with a 2000-hour rating of 4785 kW. This capacity is sufficient to power one division of safe shutdown loads needed in dealing with a station blackout event. The SBO event loading scenario was developed on a per division basis with the aid of station operators and considered a reactor initially at full power and an indefinite SBO event duration. The worst case divisional load requirements was used as the design basis for the minimum generator capacity. This capacity easily envelopes the load requirements for a LOOP or LOCA event as defined in Tables 8.3-2 and 8.3-3. Additional capacity to reduce the need for operator manual load-shedding and contingency margin of 10% was added to this minimum capacity. All loading consists of manually connected loads.

8.3.1.9.4 Components

The SBO DGs and auxiliaries are located in the Station Blackout Building. This building protects the system against weather-related events which could initiate an SBO event and provides physical isolation from safety-related components. The building is physically separated from emergency systems, thus avoiding the consequences of multiple failures of on-site diesel generator systems due to severe weather-related events. Each DG is physically separated from the other within the building. The 4kV power cables between the SBO and the safety buses are routed in cable trays outside the Reactor Building and inside the Turbine Building. The SBO building is also provided with fire detection/protection, heating, ventilation, air conditioning, and drain systems, and normal and emergency lighting. [8.3-48]

Motive power for the SBO DG is supplied by tandem (12 cylinder and 16 cylinder engines on a common shaft with the generator located in the middle) turbocharged fuel-injected Electro-Motive Division (EMD) 645F4B diesel engines. A Woodward 2301A series electronic governor with actuators is used on each diesel and is set to maintain a constant 900 rpm.

8.3.1.9.4.1 Fuel Oil Subsystem

The purpose of the fuel oil system is to provide for storage and transfer of fuel oil from the storage tank to day tank and from the day tank to the engines, as required for engine operation. The fuel oil system for the SBO DGs is entirely independent of any other fuel oil systems on-site at Quad Cities. The fuel oil system provides AC-independent transfer (engine-driven pumps) of fuel oil from a day tank, with reserve capacity for 4-hour operation, to the engines. The day tanks, in turn, can be refilled from a 15,000 gallon underground storage tank, utilizing transfer pumps.

The two SBO DGs share a common 15,000 gallon underground storage tank and short sections of common suction and return piping, located on the south side of the SBO building. Each SBO DG has its own fuel oil transfer pump which takes suction on the storage tank and a duplex strainer and discharges through a duplex filter to a 1200-gallon day tank. The transfer pump is an AC-driven, positive-displacement pump, capable of at least 15 gallons per minute, as installed. The discharge piping of each transfer pump can be cross-tied, using a manually-operated, cross-tie valve and piping to allow filling the opposite unit's day tank. The storage tank and each of the day tanks is equipped with a vent line to atmosphere through a flame arrestor to prevent overpressurization of the tanks. Overfilling of the storage tank will initiate an alarm, locally and in the control room. An overflow line on each of the day tanks back to the storage tank mitigates the consequences of overfilling of the day tanks.

The piping from the day tank to the engine provides a second flow path loop. The motive force for this loop is the engine-driven fuel oil pump which is attached to a shaft common to the lube oil scavenging pump. The system is designed so that the elevation in the day tank, at startup, is higher than the intake port of the pump, thereby ensuring the presence of fuel at the pump. The pump draws suction from the day tank, through a duplex engine-mounted strainer, and discharges through an inlet relief valve, a duplex engine-mounted filter, the injector inlet filters and into the fuel injectors. A small portion of this fuel supplied to each injector is pumped into the cylinder at very high pressure for combustion. The quantity of fuel injected depends upon the rotative position of the plunger as set by the injector rack and the governor. The excess fuel not used by the injector flows through the injector, serving to lubricate and cool the working parts. The excess fuel leaves the injectors, passes through an outlet relief valve and returns to the day tank. The inlet and outlet relief valves maintain a constant backpressure in the fuel injector manifold.

In parallel with the engine-driven fuel pump is an AC-powered fuel oil backup pump and a manual priming pump. The AC backup pump is described below. Normally, the engines are self-priming and require no priming pump. In the event that priming is required, such as post-maintenance readiness, the manual priming pump can be utilized.

The following fuel oil consumption data is for Dresden Station's Unit 2 SBO DG, using No. 2 diesel fuel oil. Quad Cities SBO DGs should have similar consumption rates.

50% load:Observed consumption 154 gallons/hr
75% load:Observed consumption 207 gallons/hr
100% load:Observed consumption 271 gallons/hr
110% load:Observed consumption 307 gallons/hr

Thus, the day tank contains enough fuel for about 4 hours of single-unit operation at 100% load without refilling. The filled storage tank, accounting for the unfilled head space, has enough fuel to operate both SBO DGs at 100% load for about 24 hours.

Manual and automatic operation of the fuel oil transfer pump is available. In the automatic mode, the pump will operate upon a signal from the distributed control system (DCS), indicating a low-normal level in the day tank. The DCS also starts the pump upon an engine shutdown. The pump stop signals are received from the DCS upon sensed high-normal level. When DCS is unavailable, an electrical bypass switch, located at Engine Control Panel 2201(2)-104 provides local manual control of the transfer pump. The AC-powered fuel oil backup pump will operate upon a sensed low fuel oil pressure of less than 25 psig, while at rated speed. This pump will sustain engine-operation in case the engine-driven pump fails. [8.3-49]

The differential pressures across the system strainers and filters, the engine fuel oil pressures, and the day tank and storage tank high and low levels are monitored and can generate local and control room alarms.

The fuel oil transfer pump and the AC backup pump are powered from MCC 65-1.

8.3.1.9.4.2 Starting Air Subsystem

The purpose of the starting air system is that, with fully pressurized receivers, the SBO DG can be started from stand-by conditions, independent of AC power availability. The SBO starting air system, consisting of two independent trains, provides full redundancy in both components and connections to supply air to the engine starting motors. Each redundant train can provide, at a minimum, five full cranking cycles without recharging its air receivers. Therefore, each DG set can receive 10 cranking cycles, independent of AC power. This capability has been proven during initial system test.

The starting air system components include an air compressor skid, a receiver skid, and engine-skid mounted components (starting air motors, air lubricators, operating valves, air regulators).

The air compressor skid holds two air compressors, two after-coolers, and two air dryers, each of which serve primarily one train. Each compressor is a 2-stage, 48 cfm capacity design, driven by a 15 HP AC-powered motor. Each after-cooler utilizes a 120-V fan to cool the air and a downstream moisture separator to remove water extracted from the air. Each air dryer is rated for 75 scfm flow at 100% RH and produces air with a -40 degree F dew point. The dryer uses chemical dessicant for moisture extraction. The dessicant is stored in two dryer towers, one of which is in the service, drying the main air stream, while the other is being regenerated with a diverted portion of the main air stream. The swapping of dryer towers occur every 5 minutes for a 10-minute drying cycle. The timing of the drying cycle is controlled by a solid state timer board. Upon failure of any dryer component, the dryer can be manually bypassed using on-skid valving. The compressor/dryer, when in the automatic mode, maintains receiver pressure.

The air receiver skid holds two 84 cu. ft. carbon steel receiver tanks, having a Maximum Allowable Working Pressure of 250 psig, each receiver serving one train primarily. A relief valve, rated to open at 250 psig, is installed on each receiver. The receivers are supplied dry air from their respective air dryer, through an inlet check valve. Inlet and outlet ball valves provide a means to isolate the receivers. The outlet valves can be used to isolate the air supply from the engine starting air motors during engine out-of-services. Cross-tie valves on the inlet side allow each compressor/dryer to be used to fill the opposite train's receiver. Cross-tie valves on the outlet side allow each receiver to supply the opposite train's starting air motors. Pressure transmitters on the receivers provide monitoring and alarms both locally and in the control room.

Each starting air train provides air to the starting motors on both engines in the set. The Train A engine-skid mounted components are located on the East side of the engine/generator skid and consists of an air regulator, a DC-operated solenoid pilot valve, a manual isolation valve, a main air-operated valve, an air lubricator, and 2 starting air motors, all on the 12-cylinder Engine A, and an air regulator, a DC-operated solenoid pilot valve, a manual isolation valve, a main air-operated valve, an air lubricator, and two starting air motors all on the 16-cylinder Engine B. The Train B engine-skid mounted components are located on the West side of the engine/generator skid and consist of similar components as for the Train A. The air regulators are maintained at approximately 175-190 psig. The DC-operated solenoid pilot valve admits air to engage the starting motor pinion gears into the engine flywheel and air to the main air-operated valve actuator. The manual isolation valve is used to isolate the engine starting motors from its starting air supply during out-of-services. The main air-operated valve, when actuated open by the supply from the pilot valve, allows air to flow to the starting motor vanes to rotate the starting motors and, in turn, crank the engine flywheel and the engine itself.

Operation of starting air system to start the SBO DG is accomplished either locally or from the main control room. A local control switch is used select the lead starting air train to be used. Using logic contained in the local programmable logic controller (PLC) and the sensed position of the control switch, the engines will crank using the selected lead train by energizing the two DC-operated solenoid pilot valves for that train. If after four seconds, the controller does not sense at least 80 rpm engine speed, it will automatically swap over to the opposite train. This swapping will continue for a total cranking time of 10 seconds, after which the start controls will lock out and provide an Overcrank alarm both locally and in the control room. Swapping is inhibited as long as the sensed engine speed is above 80 rpm. The starting motors will continue to crank until 200 rpm engine speed or the 10 second overcrank alarm and lock out is enabled. Above 200 rpm, the starting motors disengage (by de-energizing the solenoid pilot valve, venting off the pressure which causes the air motors to stop and the pinion gear to retract). Engine combustion will then provide the motive force for continued acceleration of the engines. In the PLC Bypass mode of operation (described elsewhere in this description), there is no swapping logic or overcrank alarm/lockouts. A lead starting train is selected by the local control switch and the local emergency start pushbutton must be continually depressed to start the engines. The starter motors will still disengage automatically above 200 rpm. If the selected train cannot start the engines, the control switch can select the opposite train and the start attempt repeated.

All AC-powered components of the starting air system are fed from MCC 65-1.

During SBO DG testing, the operation of the air compressors' ability to recharge the receivers and proper dryer cycling are checked.

8.3.1.9.4.3 Engine Lubrication Subsystem

A separate lubrication oil system is provided for each diesel engine, with all components on either the main skid or the engine accessory rack. During operation, the engine drives three oil pumps: the scavenging oil pump, the piston cooling oil pump, and the main bearing oil pump.

The scavenging oil pump takes a suction from the diesel engine oil sump, pumps the oil through a filter and cooler, and provides a suction to the piston cooling oil pump and main bearing oil pump.

The piston cooling oil pump supplies oil for the cooling of the piston and lubrication of the piston pin bearing surfaces.

The main bearing oil pump supplies oil for the other moving engine parts such as the main bearings, gear train, cam shaft, and rocker arms. This supply stream exits the engine and is filtered through an engine-mounted Turbo Lube Oil filter and supplies the turbocharger bearings.

During standby conditions, the engine lubrication system is kept warm by heat transferred via natural circulation from a 15-kW immersion heater (located in the cooling water system) to engine oil coolers which, in standby mode, act as heaters to heat circulating oil. The circulating oil is driven by a 1 HP, AC (motor-driven) Lube Oil Circ pump which takes suction from the engine sump and discharges to two paths. One path is through a relief check valve, the main lube oil filter, the oil heater shell-side, and the high pressure side of the engine oil strainer assembly. The other path is through the Turbo Circ Oil Filter to the turbocharger bearing. The AC Lube Oil Circ pump is designed to operate continuously, in standby or when the engine is running. The 1 HP DC (motor-driven) Lube Oil Circ pump serves as a backup. It is piped in parallel with the AC-driven pump and operates whenever the AC motor is de-energized. The Lube Oil Circ pump (AC or DC) serve two critical standby functions for the turbocharger bearings: (1) it supplies a flow of warm, filtered lubricating oil for standby readiness, and (2) it supplies a flow of cool, filtered lubricating oil for heat removal after a loaded run (soakback function).

Unlike the emergency diesel engine, the SBO engine does not provide lubrication of the crankshaft bearings during standby conditions, only the turbocharger bearings. However, each engine is equipped with a pre-lube function which can be used prior to non-emergency engine starts to lubricate not only the crankshaft bearings, but also the camshaft bearings and rocker arms (in the top deck of the engine), as well. By opening two valves downstream of the Turbo Circ Oil Filter, pressurized oil supplied by the Lube Oil Circ pump can be directed to the discharge side of the main bearing pump and supply the main oil gallery and the top deck of the engine. Pre-lubrication is done in conjunction with an engine bar-over to minimize wear and tear of engine components.

The AC Lube Oil Circ pumps are fed from MCC 65-1 and the DC Lube Oil Circ pumps are fed from Panel 6A-1. Low lube oil pressure during operation will annunciate both locally and in the control room and will also trip the engines. Operability of the lube oil system is verified during surveillance testing.

8.3.1.9.4.4 Engine Cooling Subsystem

A separate diesel generator jacket water system is provided for each diesel generator engine. The major components of each water jacket system consist of a radiator with two AC-driven radiator fans, two engine-driven jacket water pumps, an AC driven jacket water booster pump, a hotwell tank, a 3-way temperature regulating valve and a 15-kW immersion heater. The system is designed to provide adequate heat rejection via the dedicated radiators thereby, eliminating the need to interface with service water system. [8.3-50]

There is one radiator for each engine located on the SBO building roof. The radiators are air to engine coolant heat exchangers designed in accordance with API 661 and sized to provide cooling for the diesel 2000 hour rating at a maximum ambient temperature of 112°F. Each radiator has two AC powered fans that start when engine speed is greater than or equal to 200 rpm.

Two engine-driven jacket water pumps and an AC driven jacket water booster pump provide the forced circulation in the jacket water system for each engine. One engine-driven pump is located on each side of the engine and supplies loads to its half of the engine. The engine-driven pumps provide adequate cooling water at all engine speeds.

The AC driven jacket water booster pump is provided to ensure that sufficient NPSH is maintained for the two engine-driven jacket water pumps to prevent cavitation. The jacket water booster pump for the 12 cylinder engine is rated to deliver 850 gpm of flow, while the booster pump for the 16 cylinder engine is rated to deliver 1200 gpm of flow.

The 1244-gallon jacket water hotwell tanks located on the SBO mezzanine levels have sufficient capacity for adequate cooling of the diesel for seven days full load operation without makeup. In addition the hotwell tank serves as a source of cooler water so that the engine can operate without AC-driven radiator fans for up to eight minutes with the DG set at full load conditions. However, this is an unlikely mode of operation because the radiator fans are one of the first loads connected during emergencies.

A 3-way temperature-regulating valve is provided to control the temperature of the coolant. The regulating valve controls coolant temperature by passing flow through an inner and outer loop. The inner cooling loop path allows flow from the pump, through cored passages in the engine cylinder liners and cylinder heads, through the tube side of the turbocharger aftercooler to a discharge manifold where both the inner and outer loop flows rejoin, through the 3-way temperature regulating valve, through the lube oil cooler tube side, where flow is again divided and back to the pump suction. The outer loop consists of the radiator, the 1244-gallon holding tank and the jacket water booster pump. Initially flow is provided through the inner loop. As the generator is loaded and engine coolant temperature increased, the 3-way regulating valve opens allowing flow through the outer loop.

A 15-kW immersion heater in the jacket water system provides pre-warming of the jacket water and lube oil system (via the lube oil cooler) while the DG set is in the standby mode. Natural circulation forces coolant through the immersion heater to the lube oil cooler (acting as an oil "heater" in standby) and back to the immersion heater. A significant amount of convective flow through the idle coolant pumps and into the engine cylinder liners and heads also occurs. A temperature switch near the outlet of the immersion heater maintains coolant temperature between 125 and 155 degrees F and in doing so, maintains lube oil inlet temperature at greater than 95 degrees F. The control circuit is also designed to shutoff the immersion heater when the engine speed is above 200 rpm.

The jacket water coolant media is about a 50%/50% (by volume) mixture of glycol and demineralized water. A small volume of corrosion inhibitors is also part of this mixture.

A engine trip will automatically be initiated if jacket water pressure drops below 25 psig while at rated speed or if jacket water temperature exceeds 215 degrees F (Hi-Hi temperature level) while at rated or idle speed. These trips are accompanied by alarms both locally and in the control room. During emergencies, these trips are automatically bypassed. A temperature alarm of 208 degrees F (Hi temperature level) and a low expansion tank level will alarm at any time, regardless of engine operating status, locally and in the control room.

The immersion heaters and radiator fans are powered from MCC 65-1.

8.3.1.9.4.5 Engine Combustion Air and Exhaust Subsystem

Filtered outside air is drawn by the turbocharger via intake air filters located in housings on the SBO Building roof. Each engine has its own intake air filter housing. The air is compressed by the turbocharger and used to assist expelling exhaust gases from the cylinder and support combustion of fuel oil.

Engine exhaust is used to drive the turbocharger and then discharged through silencers located on the SBO Building roof. Each engine has its own silencer. Under unloaded or low loading of the generator, the turbocharger is driven by engine torque through a gear train at a rotation speed of approximately 18 times engine speed. As generator loading is increasing, a greater share of the torque needed to drive the turbocharger is borne by the increasing energy in the exhaust gases. As loading is increased past a certain limit, there is enough heat energy in the exhaust gases to provide the torque to overrun a clutch assembly and drive the turbocharger entirely off exhaust gases without gear train assist. This overrunning clutch then allows the turbocharger to speed up and run independently of the gear train; the gears continue to freewheel without transmitting torque. This is the point at which the engines achieve their highest efficiency and the minimum loading at which the engines should be run for extended periods of time.

8.3.1.9.4.6 Local Engine Control Panels

The main engine control panels (2201-104, 105, 106, 107) are housed in a common structure. These panels contain engine and generator control, monitoring, and status functions. Local operation of the generator set can be performed from the -105 panel. This panel also contains a programmable logic controller (PLC), in which many of the control and monitoring functions are embedded, and the local annunciator board. The -107 panel contains the generator protective relays and the neutral grounding transformer. Engine controls are described in Section 8.3.1.9.1, Primary Operational Characteristics.

8.3.1.9.4.7 DC Battery and Switchboard Subsystem

An independent 125 Volt DC battery system for each generator unit will provide the necessary power for 4 kV switchgear control and indications, diesel generator control and indications, lube oil standby circulation, and the uninterruptible power system (UPS) inverter.

The battery is a 58 cell 125 VDC lead-acid battery, rated at 1220 amp-hours, and is contained in its own bermed, ventilated room. The battery, its 300 A stationary battery charger, and a shared maintenance charger connects to DC Switchboard 6A or 7A. The switchboards provide feeds to the various DC loads.

The AC source for the stationary battery chargers are fed from MCC 65-1.

The Unit 1 (2) 125 Volt DC SBO battery also serves as an alternate source of control power for 4 kV buses 13-1 and 14-1 (23-1, and 24-1) (see 8.3.2.2). The battery automatically connects to the switchgear when the normal control power is not present at the feed to the switchgear. [8.3-50a]

8.3.1.9.4.8 Uninterruptible Power Supply (UPS) and Panel Subsystem

The UPS is an independent system which will provide 15kVA single phase power to the local DG control panel and the Distributed Control System (DCS) in the event of loss of normal AC power. The normal source for the UPS panelboard is a 15kVA inverter and DC switchboard. A bypass source is available through a 15kVA single-phase isolimiter transformer whose primary side is fed from MCC 65-1.

8.3.1.9.4.9 4kV Switchgear Subsystem

Figure 8.3-1 is a single-line diagram showing the 4kV connections between the SBO DGs and the plant safe shutdown buses for both Unit 1 and 2.

Dedicated 4 kV switchgear centers 61 are provided for 4 kV connections from the SBO diesel generator to the safety-related 4 kV buses. Bus 61 is connectable to either Bus 13-1 or 14-1. These connections to the safety-related buses are isolated via 2 breakers, one safety-related (located at the safety-related bus) and one non-safety-related (located at Bus 61), which are controllable from the Main Control Room.

The safety-related feed breakers from SBO at Bus 13-1 and 14-1 all operate similarly. These breakers must be closed manually from control room panel 901-74 before the associated breaker at Bus 61 can be closed. The breakers are tripped manually from control room panel 901-74. The breakers will also trip upon initiation of the EDG's auto start circuitry, if the SBO Mode Switch is in the normal mode, as it would be during surveillance test conditions.

The feed breakers at Bus 61 to Buses 13-1 and 14-1 all operate similarly. When Bus 13-1 is deenergized and the SBO Mode Switch at panel 901-74 is in SBO mode, the feed breaker can be closed without synchronizing as long as the feed breaker to Bus 14-1 is not closed. The feed to Bus 14-1 works similarly. These breakers can be manually tripped under all conditions. If the diesel generator has been reset from emergency mode at panel 901-74, then the breakers trip automatically if the diesel generator feed breaker should trip.

The SBO DG 1 generator is connectable to Bus 61 from the main control room. When Bus 61 is deenergized, the SBO Mode Switch at panel 901-74 can be placed in SBO mode and the feed breaker can be closed without synchronizing. Once the breaker is closed in this mode, and the diesel generator running in the emergency mode, only a bus fault or diesel generator faults (generator ground fault, generator differential, engine overspeed, emergency stop, or loss of PLC power) will trip this breaker. If the mode switch is returned to Normal at panel 901-74, a manual breaker trip will additionally be enabled. If the diesel generator is reset from emergency mode at panel 901-74, any diesel generator trip or normal stop of the diesel generator will trip the breaker.

The normal SBO building power source is supplied from the 13.8 to 4kV transformer T42R-6. This feed is tripped on undervoltage of the respective bus or when the respective Mode Switch at panel 901-74 is placed in SBO mode.

Buses 61 and 71 can be cross-tied to prevent blacking out half of the SBO Building when the normal feed breaker for that half is out-of-service. Interlocks prevent completing the cross-tie if any of the Bus 61 or 71 feed breakers to the safety buses are closed.

The 4 kV power cables between the SBO and safety-related switchgear are located in cable trays located outside the Reactor Building and inside the Turbine Building. [8.3-51]

8.3.1.9.4.10 Synchronizing Equipment

For the purpose of full load surveillance testing of the SBO DG to offsite power, synchronized closure capability has been installed on the following Bus 61 breakers:

Diesel generator feed breaker: to allow synchronizing the SBO DG and Bus 61.

Bus 13-1 feed breaker: to allow synchronizing the SBO DG and Division I safe shutdown buses for backfeeding to offsite.

Bus 14-1 feed breaker: to allow synchronizing the SBO DG and Division II safe shutdown buses for backfeeding to offsite.

Normal SBO power breaker: to allow synchronizing the SBO DG normal power.

Synchronizing equipment located in panel 2201-117 includes generator speed and voltage controls and synchroclosure permissive sensing devices. A HACR synchroclosure relay is also located in each of the breaker cubicles for redundancy in the synchroclosure permissive signal.

8.3.1.9.4.11 480 volt Motor Control Center (MCC) Subsystem

Dedicated 480 VAC motor control centers (MCC 65-1) are provided for distribution of station blackout auxiliary power. The MCC is fed from Bus 61 through 4kv/480 transformer 65. Load distribution is provided for the diesel auxiliaries, heating, ventilation, and air conditioning, battery chargers, lighting, and welding receptacles.

8.3.1.9.4.12 Distributed Control System (DCS)

The DCS provides remote operation of all SBO systems, primarily DG and switchgear control, from the Main Control Room. It also has a monitoring and trending function which is an important tool in the diesel generator reliability and maintenance program. The DCS receives 4-20 ma signals for analog signal monitoring and contact open/close signals for digital signal monitoring of the SBO systems status. The DCS sends digital outputs for system control via contact open/close changes.

The DCS control stations and control processors are located in the main control room panel 901-74. The application and workstation processors are located in the auxiliary electric computer room. Changes to the configuration can be made from the application processor. Interfacing with the external environment is performed through input/output panels 2201-100 and 103 and terminal cabinet 2201-101.

8.3.1.9.4.13 Heating, Ventilation, and Air Conditioning

Heating and ventilation is provided for the diesel generator rooms, the electrical equipment rooms, and battery rooms.

The design indoor conditions for the SBO Building are as follows:

Diesel Generator Rooms (diesel generators running):

Summer:	120°F maximum
Winter:	60°F minimum

Diesel Generator Rooms (diesel generators not running):

Summer:	105°F maximum
Winter:	60°F minimum

Day Tank Rooms:

Summer:	120°F maximum
Winter:	60°F minimum

Switchgear Rooms:

Summer:	104°F maximum
Winter:	60°F minimum

Battery Rooms: [8.3-52]

Nominal	77°F

The ventilation system for each diesel generator room has a maximum capacity of 95,000 CFM which is capable of maintaining the design room conditions, with the diesel generators running at full load. The ventilation systems are also capable of providing minimum and intermediate air flows at reduced room heat loads and/or to take advantage of moderate or low outdoor temperatures. The heating systems for these rooms have a total capacity of 60 kW each which will maintain the design room conditions in winter with the diesel generators in standby mode.

The ventilating system for each electrical equipment room has a maximum capacity of 20,000 CFM which is capable of maintaining the design room conditions, with the diesel generators running at full load. The ventilating systems are also capable of providing minimum and intermediate air flows at reduced room heat loads and/or take advantage of moderate or low outdoor temperatures. The heating systems for these rooms have a total capacity of 30 kW each which will maintain the design room conditions in winter.

The air conditioning systems for the battery rooms have a five ton air cooled condensing unit each, a 1600 CFM capacity air handling unit each, and an electric heater each, capable of maintaining the battery room at its nominal design conditions. An exhaust fan in each of these rooms has a continuous duty of exhausting 350 CFM of room air to provide the required minimum room ventilation of four changes per hour for the removal of hydrogen gas generated by the batteries. The exhaust fans are interlocked with the fire alarm system to shut down on fire alarm actuation.

The exhaust systems in the day tank rooms have a continuous duty of exhausting 250 CFM of room air to provide the required minimum ventilation of four air changes per hour for the removal of diesel fumes. The exhaust fans are interlocked with the fire alarm system to shut down on fire alarm actuation.

Power for SBO HVAC is provided by MCC 65-1.

8.3.1.9.4.14 Fire Protection System

The SBO Building and equipment are protected from fire by fire hoses in the main rooms of the building and a wet pipe sprinkler system in each of the diesel rooms and day tank rooms. The source of water is the main fire ring header. Alarms are generated when these water systems are actuated.

A smoke and heat detection system is installed in the rest of the SBO building.

8.3.2 DC Power Systems

Station batteries are provided as a final source of dc power for specific vital loads and control power. Three station battery systems (250-V, 125-V and 24/48-V) are provided for each unit. A separate non-essential 250 VDC system is installed in Unit 1 and Unit 2 to provide service for non-safety related loads. The 250-V "power" battery systems are provided to serve the larger loads such as dc motor-driven pumps, valves, etc. The 125-V "control" battery is provided to supply the power required for all dc control functions such as that required for control of 4160-V breakers, 480-V breakers, various control relays, annunciators, etc. [8.3-53]

An alternate 125-V battery is provided to allow testing of the unit 125-V battery while both units remain at power. The alternate 125-V battery is also available upon the inoperability of the unit 125-V battery. Two 24/48-V batteries are provided to supply the neutron monitoring system. [8.3-54]

The 250-V, 125-V and 24/48-V batteries for each unit are located in a ventilated battery room having concrete walls. The Unit 1 and Unit 2 non-essential 250-V batteries are not located in a ventilated battery room. The Unit 1 non-essential 250-V battery is located near the southwest corner of the Turbine Building at floor elevation 639 ft. and is enclosed with a safety fence. The Unit 2 non-essential 250-V battery is located near the northwest corner of the Turbine Building at floor elevation 639 ft. and is enclosed with a safety fence. The Unit 2 125-V alternate battery is located outside the battery room (refer to Section 8.3.2.2). Voltmeters are installed in the control room to indicate battery voltage for the 24/48-V, safety-related 125-V and 250-V systems. Each meter reads directly off the battery. [8.3-55]

8.3.2.1 250-V System

There are two 250-V systems, one per unit. The basic function of the 250-V battery is to supply electrical power to the dc distribution systems whenever the battery charger, which supplies the normal source of power, fails. The safety-related 250-V battery system of each unit is sized to start and carry the normal dc loads plus all dc loads required for safe shutdown on one unit, and the operational loads required to limit the consequences of a design-basis event on the other unit, for a period of four hours following loss of offsite power plus a single active failure without taking credit for the battery charger. These loads are summarized in the load tracking database. This time period is deemed adequate to safeguard the plant until normal sources of power are restored. [8.3-56]

Although the battery chargers are designed to function during a Design Basis Event, a worst case battery profile has been developed for sizing the 250-V battery. This worst case profile does not assume a battery charger is available and is more conservative than the system requirements described in the UFSAR Chapter 15 accident and transient analyses. The implementation of the conservative profile for battery sizing requires manual load shedding of non-essential loads within 30 minutes in the event that an analyzed accident and/or transient were to occur simultaneously with the unavailability of both the dedicated charger and the swing charger. This load shedding would be required to provide adequate margin in the 250-V battery if it were utilized as a long-term power source.

A separate non-essential 250 VDC system is installed in Unit 1 and Unit 2 to provide service for non-safety loads. The non-essential 250 VDC system is completely physically and functionally separate from the safety related 250-V system. The non-essential 250 VDC consists of two battery chargers (one backup charger), a battery bank and 250-V Motor Control Center (MCC) in each unit. Unless otherwise noted, the following paragraphs of this section (8.3.2.1) describe the safety related 250-V systems of Units 1 and 2.

The three 62.5-kW battery chargers (one per unit and a swing charger) are sized to restore the battery to full charge under normal load conditions. The chargers are powered from separate ac buses. These buses are arranged so that they can be connected to one of several sources of ac power available in the plant, including the diesel generator. The battery chargers are supplied from MCC 19-2 for Unit 1, MCC-29-2 for Unit 2, and either MCC 18-2 or 28-2 for the swing charger. These multiple and diverse power supplies to the 250-V battery chargers for each unit ensure a high degree of reliability that a charger will be available during normal plant configuration and any Design Basis Event. The dedicated battery charger for each unit and the swing charger are fed from different diesel generators to assure charger availability during a Loss of Offsite Power (LOOP).

The 250-Vdc MCCs are normally fed from their primary source (charger) and their secondary source (battery) operating in a "float-charger" configuration. Loss of either source does not interrupt power flow to the bus. The voltage is raised as necessary for equalization of the charge on the battery cells. [8.3-57]

The capacity of each unit battery is adequate to supply expected essential loads following station trip and loss of all ac power without battery terminal voltage falling below the minimum discharge level (i.e., 210-V). [8.3-58]

All of the loads normally connected to the 250-Vdc system, except the heavy duty loads, can be supplied by either charger. Buses are arranged to allow for alternate paths to other systems throughout the plant where redundancy is employed. Direct connected loads are shown in Table 8.3-4, also refer to the most recent version of the load tracking database. [8.3-59]

The 250-V battery system operates ungrounded with a recording ground-detection voltmeter and alarm (alarm in the main control room) to annunciate the first ground. In addition, the ground fault resistance, and time at which the ground fault occurs, is recorded by a recording voltmeter. Thus, multiple grounds, the only reasonable mode of failure, are extremely unlikely. The normal mode of battery failure is a single cell deterioration which is signaled well in advance by the routine tests which are performed regularly on the battery. [8.3-60]

When a ground is identified, the action that is taken is determined by the ground's level. If it is a Level I ground (greater than the alarm setpoint of 125,000 ohms), it is recorded and tracked each shift. If it is a Level II ground (125,000 ohms - 40,000 ohms) station procedures are implemented immediately to locate and remove the ground. Additionally, a "DC System Ground Report" (or station equivalent form) shall be generated as input to the station's files. If the ground is a Level III, (less than 40,000 ohms) the station has 14 days to repair it and generate a DC System Ground Report. If a Level III ground cannot be eliminated within 14 days and the ground must remain on the system, enter the operability determination process. If an intermittent ground occurs, it shall be logged with the time, date, and coincident activities.

The two heavy-duty buses furnish power to the loads, most of which are connected only in an emergency condition (see drawings 4E-1317 and 4E-2317). In general, these loads are motor loads such as backup isolation valves and emergency lube oil pumps where the power source is the main battery. [8.3-61]

The essential 250-Vdc distribution system for each unit consists of three MCCs: turbine building MCC 1(2), and the reactor building MCCs 1A and 1B (2A and 2B). Turbine building MCC 1 supplies 250-Vdc loads in the turbine building, such as coastdown lubricating oil pumps and valve operator motors, and is fed from the Unit 1 battery bus. Reactor building MCC 1A supplies all of the essential 250-Vdc electrical loads for the HPCI system, and is normally supplied from turbine building MCC 1. An alternate supply for MCC 1A is from reactor building MCC 1B (via a removable link). This ensures a diversity of power sources for HPCI. Reactor building MCC 1B supplies all of the essential 250-Vdc electrical loads for the RCIC system, and is normally supplied from the turbine building MCC 2. [8.3-62]

The Unit 2 250-Vdc system is similar to the Unit 1 system.

8.3.2.2 125-V System

There are two 125-V battery systems, one per unit. The basic function of the 125-V battery is to supply electrical power to the dc distribution systems whenever the battery charger, which supplies the normal source of power, fails. The 125-Vdc power system supplies power to control circuits, switchgear, the turbine system and safety injection systems. [8.3.63]

The 125 V battery system of each unit is sized to start and carry the normal dc loads plus all dc loads required for safe shutdown on one unit and the operational loads required to limit the consequences of a design-basis event on the other unit, for a period of four hours following loss of offsite power plus a single active failure without taking credit for the battery charger. These loads are summarized in the load tracking database. This time period is deemed adequate to safeguard the plant until normal sources of power are restored. [8.3-64]

Although the battery chargers are designed to function during a Design Basis Event, a worst case battery profile has been developed for sizing the 125-V battery. This worst case profile does not assume a battery charger is available and is more conservative than the system requirements described in the UFSAR Chapter 15 accident and transient analyses. The implementation of the conservative profile for battery sizing requires manual load shedding of non-essential loads within 30 minutes in the event that an analyzed accident and/or transient were to occur simultaneously with the unavailability of both the dedicated charger and the backup charger. This load shedding would be required to provide adequate margin to the 125-V battery if it were utilized as a long-term power source.

There are four 25.0-kW battery chargers (one normal and one backup per unit). Each is sized to restore its connected battery to full charge under normal load conditions. The chargers are powered from separate ac buses which are arranged so that they can be connected to one of several sources of ac power available in the plant, including the diesel generator. The battery chargers are supplied from: MCC 19-2 for charger 1, MCC 18-2 for charger 1A, MCC 29-2 for charger 2, and MCC 28-2 for charger 2A. These multiple and diverse power supplies to the 125-V battery chargers for each unit ensure a high degree of reliability that a charger will be available during normal plant configuration and any Design Basis Event. The two dedicated battery chargers for each unit are fed from different diesel generators to assure charger availability during a Loss of Offsite Power (LOOP).

The 125-Vdc buses and distribution panels are normally fed from their primary source (charger) and their secondary source (battery) operating in a "float-charger" configuration. Loss of either source does not interrupt power flow to the bus. The voltage is raised as necessary for equalization of the charge on the battery cells. [8.3-65]

The capacity of each unit battery is adequate to supply expected essential loads following station trip and loss of all ac power without battery terminal voltage falling below the minimum discharge level (i.e., 105-V). [8.3-66]

All of the loads normally connected to the 125-Vdc system can be supplied by either charger. The chargers can be powered from multiple sources of station auxiliary power including the DG. Buses are arranged to allow for alternate paths to other systems throughout the plant where redundancy is employed. The aggregate system is so arranged and powered that the probability of system failure due to loss of 125-Vdc power is very low. Directly connected loads that are included are shown in Table 8.3-5. Refer to the most recent version of the load tracking database. [8.3-67]

The 125-V battery system operates ungrounded with a recording ground-detection voltmeter and alarm (alarm in the main control room) set to annunciate the first ground. In addition, the ground fault resistance, and the time at which a ground fault occurs, is recorded by a recording voltmeter. Thus multiple grounds, the only reasonable mode of failure, are extremely unlikely. The normal mode of battery failure is a single cell deterioration which is signalled well in advance by the routine tests which are performed regularly on the battery. [8.3-68]

When a ground is identified, the action that is taken is determined by the ground's level. If it is a Level I ground (greater than the alarm setpoint of 125,000 ohms), it is recorded and tracked each shift. If it is a Level II ground (125,000 ohms - 20,000 ohms) station procedures are implemented immediately to locate and remove the ground. Additionally, a "DC System Ground Report" (or station equivalent form) shall be generated as input to the station's files. If the ground is a Level III (less than 20,000 ohms) the station has 14 days to repair it and generate a DC System Ground Report. If a Level III ground cannot be eliminated within 14 days and the ground must remain on the system, enter the operability determination process. If an intermittent ground occurs, it shall be logged with the time, date, and coincident activities.

Each unit has been provided with an alternate 125-V battery in order to allow the unit 125-V battery to undergo testing while both units remain at power. The alternate battery is available to supply system loads upon a failure of the unit 125-V battery. The alternate battery has the same design and performance characteristics as the unit battery. The alternate battery is normally disconnected from the system. [8.3-69]

The Unit 1 alternate 125-V battery is seismically installed in the Unit 1 battery room. The battery room provides the same protection for the Unit 1 alternate battery as a Class I structure. The Unit 2 alternate 125-V battery is seismically installed outside the Unit 2 battery charger room on the turbine building mezzanine floor, between columns 1 and 2, and between rows E and F. The turbine building provides the same protection for the Unit 2 alternate battery as a Class I structure, except for the case of tornado missiles. However, a probabilistic analysis has been performed which shows that limiting the period that the alternate battery is relied upon to less than 52 days in any calendar year limits the probability of a tornado missile striking the battery while it is relied upon to less than 10^{-7}. The period that the Unit 2 alternate battery is relied upon is limited to less than 52 days in any calendar year. There are no limitations on the Unit 1 alternate battery.

The station battery is an integral part of the 125-Vdc system which includes the battery chargers, breakers, buses, and other auxiliaries (see 4E-1318B). The following description for the Unit 1 125-Vdc system is similar to that for Unit 2. [8.3-70]

The Unit 1 turbine building main bus number 1A is supplied from the Unit 1 battery system and is the normal source of control power for Unit 1 main essential bus 1A-1, main non-essential bus 1A-2, main control room panels, relay panels, 4160-V and 480-V switchgear (in the turbine building), reactor building distribution panel number 1 and the Unit 2 turbine building reserve bus 2B. It is the reserve source of control power to the Unit 1 turbine building reserve bus 1B-1.

The Unit 1 reactor building distribution panel is the normal source of control power for the Unit 1 4160-V switchgear 13-1 and 480-V switchgear 18. It is the reserve source of control power to Unit 1 4160-V switchgear 14-1 and 480-V switchgear 19.

The Unit 1 turbine building reserve bus number 1B is normally supplied from the Unit 2 turbine building main bus 2A and is the normal source of control power for turbine building reserve bus 1B-1 and turbine building reserve bus 1B-2.

The Unit 1 turbine building reserve bus 1B-1 is the normal source of control power for the 4160-V switchgear 14-1 and 480-V switchgear 19. It is the reserve source of control power for 4160-V switchgear 13-1, 480-V switchgear 18 and reactor building distribution panel number 1.

It is thus noted that the control power for one set of reactor building switchgear is completely independent (including the unit battery) from the control power to the other set of reactor building switchgear.

In additional alternate source of control power for Unit 1 4160-V switchgear 13-1 and 14-1 is the 125 VDC battery that serves the Unit 1 Station Blackout (SBO) diesel subsystems (see 8.3.1.9.4.7). Upon sensing loss of control power at the feed to each switchgear, a safety-related transfer switch automatically connects the SBO battery to the switchgear through DC Switchboard 6A. [8.3-70a]

Independence of control power between the two sets of switchgear could be lost if the normal control power to both switchgear is lost simultaneously. However, the manually connectable independent alternate sources described above remain available and could be utilized to regain independence.

A 125-Vdc control power crosstie exists between 4160-V switchgear 13-1 and 23-1. It is controlled by two manually-operated circuit breakers with 100A frames with no trip elements. These breakers are located on either end of the crosstie and are kept open and have a locking clip to prevent inadvertent closure of the breakers. The function of the crosstie is no different than the function of the existing reserve feed. The electrical independence of the control power between the switchgear will only be compromised when the crosstie is in use. The crosstie ensures that a reserve feed will be available in the event that a fire destroys the existing main and reserve feeds to the 4160-V switchgear. [8.3-71]

8.3.2.3 Nuclear Instrument Supply Systems 24/48 Volts DC

The electrical supply for the source range monitor and intermediate range monitor systems consists of two duplicate 24/48-V 3-wire, grounded neutral systems(see FSAR Figure 8.3-2). Each system consists of two 24-V, 170 Ah or greater (eight hour rate) batteries in series and connected to a dc distribution panel. There are two silicon rectifier type 50-A battery chargers on each system, one of which is connected to each of the 24-V batteries. The source of power for the battery chargers is the 120-Vac instrument bus. Each 24/48-V system is equipped with undervoltage and overvoltage alarms. The battery chargers are capable of completely recharging the battery in approximately six hours while simultaneously supplying the normal continuous load of 8 A (estimated). [8.3-72]

The 24/48-V distribution panels are arranged to allow for alternate electrical paths to other systems throughout the plant. [8.3-73]

Local indications exist in the Units 1 and 2 battery charger room for: charger voltage and current, bus A and B positive and negative voltage. [8.3-74]

8.3.2.4 Tests and Inspections

The station batteries and other equipment associated with the 24/48-, 125-, and 250-Vdc system are easily accessible for inspection and testing. Service and testing are accomplished on a routine basis in accordance with recommendations of the manufacturer and the Technical Specifications for the 125 and 250 vdc system. Typical inspections would include visual inspections for leaks and corrosion; checking all batteries for voltage, specific gravity, electrolyte level, and temperature; and performing a simulated load test. [8.3-75]

Table 8.3-1

SIGNIFICANT AUXILIARY ELECTRICAL SYSTEM EQUIPMENT LISTING
(Unit 1 Shown - Typical for Units 1 and 2 Except Main Transformer or As Noted)

EQUIPMENT	RATING/SIZE
Transformers	
TR-1 - Main (Unit 1) TR-2 - Main (Unit 2)	982/1100 MVA 18 — 362.25kV (Unit 1) 982/1100 MVA 18 — 362.25kV (Unit 2) 1050 kV BIL, 3 Phase, 60 Hz, FOA 55 degrees/65 degrees rise Impedance 12.61% (Unit 1) & 12.65% (Unit 2)
TR-11 - Unit Auxiliary Power	27.6/36.8/46 MVA @ 55°, 18.00-4.26-4.26 kV, 150 kV BIL 3 Phase, 60 Hz, OA/FA^{I}/FA^{II}, 55 degrees C (65 degrees C) Impedance: H-X-27.8 $\pm$ 10% Min. H-Y-21.2 $\pm$ 10% Min. X-Y-50.0 $\pm$ 10% Min. Winding Ratings: H-27.6/36.8/46 MVA (30.9/41.2/51.5 MVA) X-11.4/15.2/19 MVA (12.8/17/21.3 MVA) Y-16.2/21.6/27 MVA (18.1/24.2/30.2 MVA)
TR-21 - Unit Auxiliary Power	37.5/50.0/62.5 MVA, 18.0-4.368-4.368 kV, 150 kV BIL, 3 Phase, 60 Hz, ONAN/ONAF/ONAF, 65° C Impedance: H-X-10.46% H-Y-7.96% X-Y-17.78% Winding Ratings: H-37.5/50/62.5 MVA 65° C X-18.75/25/31.25 MVA 65° C Y-18.75/25/31.25 MVA 65° C
TR-12 - Reserve Auxiliary Power	37.5/50/62.5 MVA, 345-4.3-4.3 kV, 3 Phase, 60 Hz, ONAN/ONAF/ONAF, 1050 kV BIL, 65 degree C rise Winding Ratings: H - 37.5/50.0/62.5 MVA (65 degree C) X - 18.75/25.0/31.25 MVA (65 degree C) Y - 18.75/25.0/31.25 MVA (65 degree C) X-Winding Load Tap Changer: 32 positions from nominal of + 25% to – 5% of rated voltage
TR-81 - Spray Canal	Service Date: 8/13/74 25/33/42 MVA, 345-13.8 kV, 3 phase, 60 Hz OA/FA/FA

Table 8.3-1

SIGNIFICANT AUXILIARY ELECTRICAL SYSTEM EQUIPMENT LISTING
(Unit 1 Shown - Typical for Units 1 and 2 Except Main Transformer or As Noted)

EQUIPMENT	RATING/SIZE
TR-15, 16, 17, 18, 19	1500 kVA, 4.16 kV - 480 V, 3 Phase, 60 Hz, OA cooled, 55 degrees C rise Impedance 9.7% Min.
TR-31	225 kVA, 4.16 kV-480/277V, 3 Phase 160 Hz
TR-10	Off Gas Filter Building 500 kVA, 4160-480, 3 Phase, 60 Hz, OA cooled, 65 degrees C Rise Impedance 4.7%
TR-1A	Radwaste Max recycle transformer 750 kVA, 4160-480, 3 Phase, 60 Hz, OA cooled, Impedance 5.5%
Gatehouse Auxiliary Transformer	750 kVA, 4160-480, 3 Phase, 60 Hz Impedance 5.75%
Circuit Breakers	
4.16-kV Buses 11 and 12	
Incoming	4 - AM 4.16 - 350 MVA, 3000 A.
Feeders	6 - AM 4.16 - 350 MVA, 1200 A.
4.16-kV Bus 13	
Incoming	2 - Vacuum 4.16 - 350 MVA, 2000 A.
Feeders	11 - Vacuum 4.16 - 350 MVA, 1200 A.
4.16-kV Bus 14	
Incoming	2 - Vacuum 4.16 - 350 MVA, 2000 A.
Feeders	12 - Vacuum 4.16 - 350 MVA, 1200 A.
4.16-kV Bus 24	
Incoming	2 - SF_6 4.16 - 350 MVA, 2000 A
Feeders	12 - Vacuum 4.16 - 350 MVA, 1200 A
4-16-kV Buses 13-1 and 14-1	
Incoming	6 - SF_6 4.16 - 350 MVA, 1200 A.
Bus Ties	2 - SF_6 4.16 - 350 MVA, 1200 A.
Feeders	12 - SF_6 4.16 - 350 MVA, 1200 A.
4.16-kV Buses 23-1 and 24-1	
Incoming	6 - SF_6 4.16 - 350 MVA, 1200 A.
Bus Ties	2 - SF_6 4.16 - 350 MVA, 1200 A.
Feeders	10 - SF_6 4.16 - 350 MVA, 1200 A.

Table 8.3-1

SIGNIFICANT AUXILIARY ELECTRICAL SYSTEM EQUIPMENT LISTING
(Unit 1 Shown - Typical for Units 1 and 2 Except Main Transformer or As Noted)

EQUIPMENT	RATING/SIZE
480-V Switchgears 15, 16, 17	
Incoming	3 - AK - 75
Bus Ties	2 - AK - 50
Feeders	42 - AK – 25
480-V Switchgears 18 and 19	
Incoming	2 - AK - 75
Bus Ties	1 - AK - 50
Feeders	24 - AK - 25
Bus Duct	
Main Generator Leads	
Iso-Phase Bus Section	
Auxiliary Transformer Tap	Self-Cooled Rating – 2,000 Amps Force-Cooled Rating – NA
Generator Bus	Self-Cooled Rating – 14,700 Amps Force-Cooled Rating – 17,130 Amps
Main Bus	Self-Cooled Rating – 19,500 Amps Force-Cooled Rating – 34,256 Amps
Unit and Reserve Secondary Feeders	
Winding "X" to Switchgear	3/4 Non-Segregated, 3000 A.
Winding "Y" to Switchgear	3/4 Non-Segregated, 4100 A.
Generators	
G1	1068 MVA, 0.945 PF, 0.52 SCR, 18 kV, 1800 rpm, 3 Phase, 60 Hz, 60 psig H_2
EDG's	Diesel Driven, 4.16 kV, 3 Phase, 60 Hz, 0.8 PF
	Continuous Rating (8000 hr/yr): 2600kW, 3250 kVA with 110% overload capability for two hours out of any 24 hours
	2000 hr/yr: 2864 KW, 3575 kVA
	200 hr/yr: 2973 KW
	4 hr/yr: 3009 KW
	30 min/yr: 3064 KW
SBO DGs	Diesel Driven, 5437.5 kVA, 4350 kW, 0.8 PF, 4.16 kV, 3 phase, 60 Hz
	(Peak Rating: 5981.25 kVA, 4785 kW, (2000 hrs/yr)

Table 8.3-1

SIGNIFICANT AUXILIARY ELECTRICAL SYSTEM EQUIPMENT LISTING
(Unit 1 Shown - Typical for Units 1 and 2 Except Main Transformer or As Noted)

EQUIPMENT* **	
Equipment Data Sheet - Electrical Bus Loads	
4160-V Bus 11	1 - Reactor feed pump 1 - Reactor recirculating pump adjustable speed drive 1 - Feeder to reactor feed pump 1C**
4160-V Bus 12	1 - Reactor feed pump 1 - Reactor recirculating pump adjustable speed drive 1 - Feeder to reactor feed pump 1C**
4160-V Bus 13	2 - Circulating water pump 2 - Condensate and booster pump 1 - Service water pump 2 - RHRS service water pump 1 - Control rod drive feed pump 1 - 480-V switchgear 15 1 - 4160-V bus 13-1 1 - 480-V switchgear 1A
4160-V Bus 14	1 - Circulating water pump 2 - Condensate and booster pump 2 - Service water pump 2 - RHRS service water pump 1 - Control rod drive feed pump 2 - 480-V switchgears 16 and 17 1 - 4160-V bus 14-1 1 - 480-V feed to well water pump #5 (Unit 2)
4160-V Bus 13-1	1 - Core spray pump 2 - RHRS pump 1 - 480-V switchgear 18 1 - 480-V transformer at pump house (Unit 1) 1 - 480-V switchgear 10 (offgas) 1 - 4160-V tie to bus 23-1

** Pump 1C may be fed from either Bus 11 or Bus 12
*** For rating/size of equipment, refer to the most recent version of the load tracking database.

Table 8.3-1

SIGNIFICANT AUXILIARY ELECTRICAL SYSTEM EQUIPMENT LISTING
(Unit 1 Shown - Typical for Units 1 and 2 Except Main Transformer or As Noted)

EQUIPMENT*	
Electrical Bus Load (Continued)	
4160-V Bus 14-1	1 - Core spray pump 2 - RHRS pump 1 - 480-V switchgear 19 1 - 4160-V tie to bus 24-1 1 - Feed to the Gatehouse (security building) (Unit 1) 1 - Feed to SSMP Bus 31
480-V Switchgears 15, 16, 17	2 - Turbine building exhaust fans 2 - EHC fluid pumps 2 - Main power transformer cooling equipment 3 - Turbine and service building lighting (includes Control Room) 1 - Control room air conditioning chiller 1 - Condenser vacuum pump 2 - Service air compressor 1 - Instrument air compressor 1 - Turbine building cranes 1 - High radiation sample building 2 - Radwaste air sparging compressors 19- Motor control centers (16 Unit 2) 1 - Computer UPS 1 - ESS UPS 2 – Automatic Voltage Regulator
480-V Switchgears 18 and 19	2 - Fuel pool cooling pump 9 - Reactor and turbine building vent fans 1 - 120/240-V essential service bus static inverter 11 - Motor control centers (10 Unit 2) 2 - Diesel cooling water pumps 3 - Reactor building closed cooling water pump 1 - Instrument air compressor 2 - Reactor and turbine building lighting

*** For rating/size of equipment, refer to the most recent version of the load tracking database.

Table 8.3-2

Major Emergency Diesel Generator Loads During LOOP Without LOCA

	0 — 10 Minute Auto Loading	Loads After 10 Minutes
Service Water Pump (1)	--	950 HP
CRD Pump (1)	--	250 HP
Lighting Loads	255 kW	468 kW
Service Air Comp (1)	--	112.5 HP
Fuel Pool CWP (1)	--	90 HP
RBCCW Pump (1)	105 HP	105 HP
480 Volt MCCs	863 kVA	949 kVA
Drywell Coolers (3 total)	252 HP	252 HP
SBLC Tank Heater (1)	60 kW	60 kW
Battery Chargers (6 total)	348 kVA	348 kVA
Rx Feed Pump Vent Fan (1)	50 HP	50 HP
Control Room HVAC	50 HP	125 HP
EDG Cooling Water Pump (1)	90 HP	90 HP
Panel loads (1)	89 kVA	89 kVA
UPS Panel (1)	61 kVA	60 kVA
Misc. Transformer Loads (2)	82 kVA	82 kVA

Notes:

1. The loading values provided in this table are nominal values. For detailed evaluation of EDG loading and the actual analyzed loading values, refer to the most recent version of the load tracking database and the supporting design analyses (calculations).

2. ( ) = Number of Components

3. Loads listed in this table are 50 HP or greater (approx.)

Table 8.3-3

Major Emergency Diesel Generator Loads During LOOP Concurrent with LOCA

	0 — 10 Minute Auto Loading	Loads After 10 Minutes
RHR SW Pump (1)	--	1029 HP
Core Spray Pump (1)	898 HP	898 HP
RHR Pump (2 @ 600 HP)	1258 HP	639 HP
Lighting	175 kW	175 kW
480 Volt MCCs	700 kVA	700 kVA
SBLC Tank Heater (1)	60 kW	60 kW
Rx Feed Pump Vent Fan (1)	50 HP	50 HP
Control Room HVAC	50 HP	125 HP
EDG Cooling Water Pump (1)	90 HP	90 HP
Battery Chargers (6)	350 kVA	350 kVA
Panel Loads (1)	89 kVA	89 kVA
UPS Loads (1)	61 kVA	61 kVA
Misc. Transformer Loads (2)	95 kVA	15 kVA
MOV Loads (1)	52 HP	--

Notes:

1. The loading values provided in this table are nominal values. For detailed evaluation of EDG loading and the actual analyzed loading values, refer to the most recent version of the load tracking database and the supporting design analyses (calculations).

2. ( ) = Number of Components

3. Loads listed in this table are 50 BHP or greater (approx.)

Table 8.3-4

DIRECT CONNECTED LOAD
250 Vdc
(Typical for one unit)

1. AC essential service bus static inverter
2. Deleted
3. HPCI turbine auxiliary oil pump
4. HPCI turbine emergency bearing oil pump
5. Emergency generator hydrogen seal oil pump
6. HPCI turbine turning gear
7. HPCI gland steam condenser exhauster
8. Motor-operated valves at 2 hp each (29)
9. HPCI gland seal condenser hotwell drain pump
10. Turbine building closed cooling water heat exchanger isolation valve
11. Fire protection system service water valve
12. Hydrogen and stator cooler service water supply valve
13. Deleted
14. RCIC turbine condensate pump
15. RCIC turbine vacuum pump

For specific loads refer to the most recent version of the load tracking database.

Table 8.3-5

DIRECT CONNECTED LOAD
125 VDC
(Typical for one unit)

1. Escape Lighting
2. Annunciator relay cabinet and visual annunciator
3. Radwaste System Control Power
4. Plant sirens
5. Relief Valves
6. Fire Protection System (CO_2 and Deluge)
7. 480/4160 Volt circuit control power (11 main feeds)
8. Deleted
9. RCIC System Logic
10. Emergency Diesel Generator Logic / Field Flashing
11. HPCI System Logic
12. Reactor / Turbine Building HVAC System
13. Main Generator / Transformer Control Logic
14. RHR System Logic
15. PCI / TIP System
16. Core Spray System Logic
17. CAM/CAD System
18. ATWS System

19 Backup Scram Valves

20. D.A.C. / Telephone System
21. Standby Condensate Pump Control Logic
22. Reactor / Turbine Building Doors

For specific loads refer to the most recent version of the load tracking database.

Table 8.3-6

BUS LOADINGS ASSUMED FOR
OFFSITE POWER SUPPLY ANALYSIS

Quad Cities Unit 1

Bus 11……………………………………………..12.9 MVA

Bus 12…………………………….……………12.9 MVA

Subtotal……………….………………………25.8 MVA

Bus 13………………………………………… 15.0 MVA

Bus 14………………………………………… 13.4 MVA

Subtotal………………………………………..28.4 MVA

Approximate Unit 1 Loading……………..…54.2 MVA

Bus 21…………………………………….……12.9 MVA

Bus 22 ……………………………………..…..12.9 MVA

Subtotal………………………………………25.8 MVA

Bus 23……………………………….………..14.2 MVA

Bus 24…………………………………………13.8 MVA

Subtotal………………………………………28.0 MVA

Approximate Unit 2 Loading ……………..53.8 MVA

Table 8.3-7

RUNNING VOLTAGES TO SELECTED LOADS

Load	HP	Rated Voltage (volts)	Running* Volts	Percent of Motor Rated	Bus
Reactor Feed Pump	9000	4000	3855	96.4	11 + 12
Circulating Water Pump	1750	4000	3909	97.7	13 + 14
Service Water Pump	1000	4000	3909	97.7	13 + 14
Cond. & Cond. Boost Pump	1750	4000	3909	97.7	13 + 14
Rx Bldg. Exhaust Fan 1B	100	460	443	96.3	480 V Swgr Bus #19
Reactor Feed Pump	9000	4000	3980	99.5	21 + 22
Circulating Water Pump	1750	4000	3840	96.0	23 + 24
Service Water Pump	1000	4000	3840	96.0	23 + 24
Core Spray Pump	800	4000	3840	96.0	24-1
RHRS Pump	600	4000	3840	96.0	24-1
Rx Bldg. Exhaust Fan 2A	100	460	435	94.6	480V Swgr Bus #28

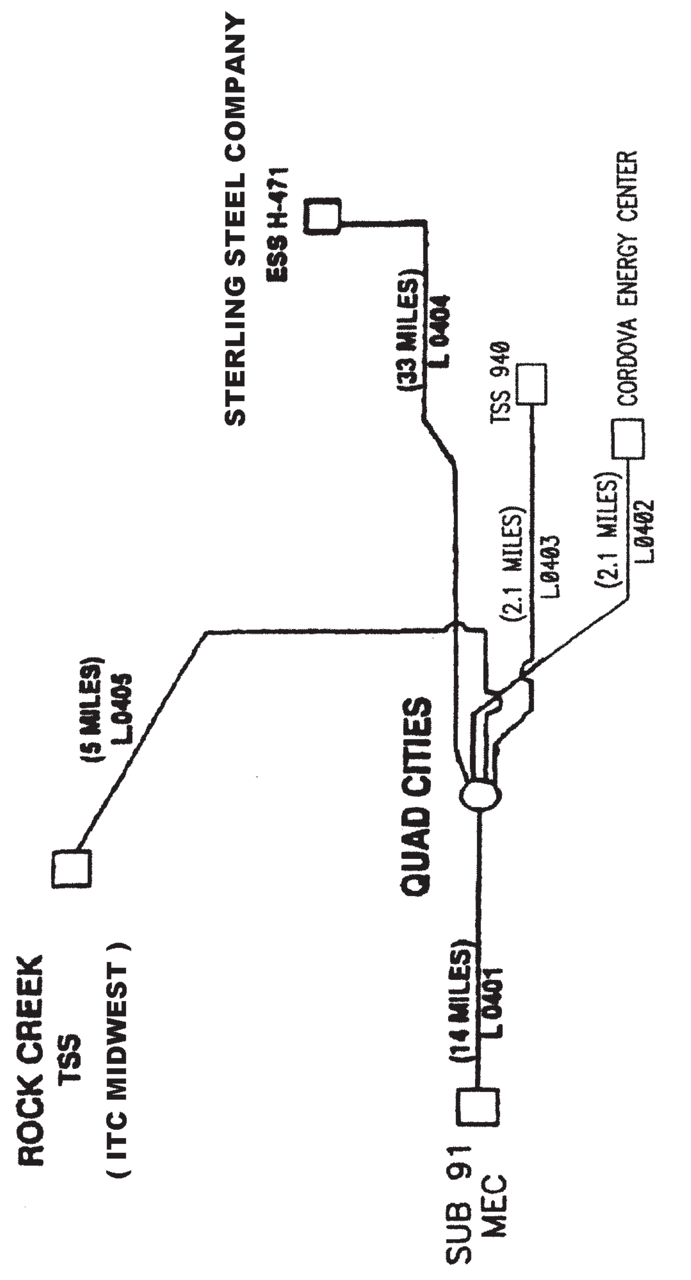
* Voltages do not include the voltage drop in the cables from the bus to the load.

Table 8.3-8

AUXILIARY SYSTEM ELECTRICAL PERFORMANCE

	No Load Voltage	Full Load Voltage	Motor Starting Voltage	HP
345kV Bus Voltage (kv)	354	333	333	
% of 345kV	102.6	96.5	96.5	
4.16kV Buses 11 & 12 (kV)	4.378	3.855	3.086	9000 hp
% of 4.16kV	105.2	92.7	74.2	
% of 4.0kV	109.4	96.4	77.2	
4.16kV Buses 13 & 14 (kV)	4.378	3.909	3.684	1750 hp
% of 4.16kV	105.2	94.0	88.5	
% of 4.0kV	109.4	97.7	92.1	
4.16kV Buses 21 & 22 (kV)	4.378	3.980	3.215	9000 hp
% of 4.16kV	105.2	95.7	77.3	
% of 4.0kV	109.4	99.5	80.4	
4.16kV Buses 23 & 24	4.378	3.840	3.616	1750 hp
% of 4.16kV	105.2	92.3	86.9	
% of 4.0kV	109.4	96.0	90.4	
480V Bus 19 (V)	518	443		
% of 480V	108	92.3		
% of 460V	112.6	96.3		
480V Bus 28 (V)	518	435		
% of 480V	108	90.6		
% of 460V	112.6	94.6		

Note: This table represents values from the original design analysis. For current values, refer to the load tracking database.

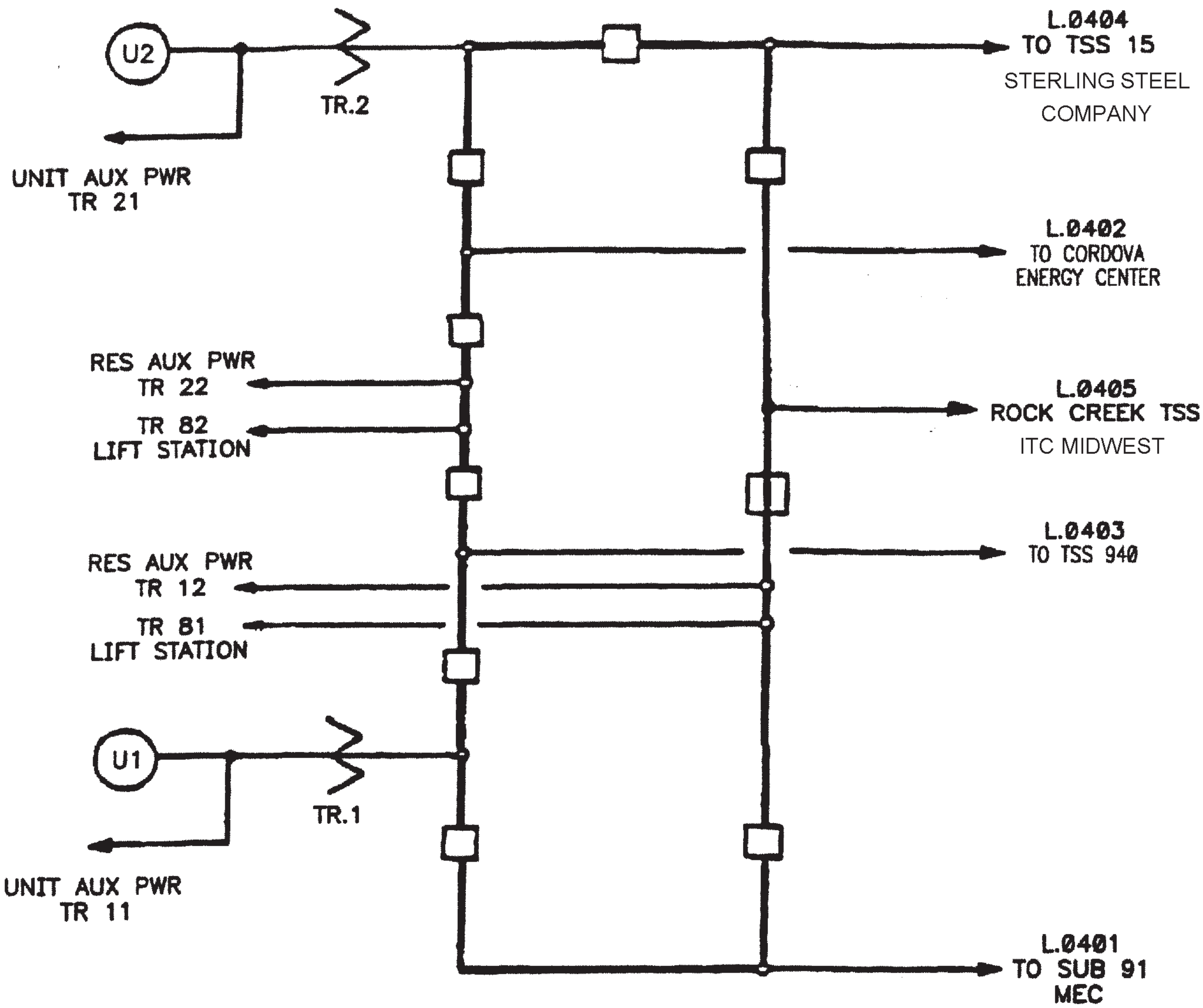


QUAD CITIES STATION UNITS 1 & 2

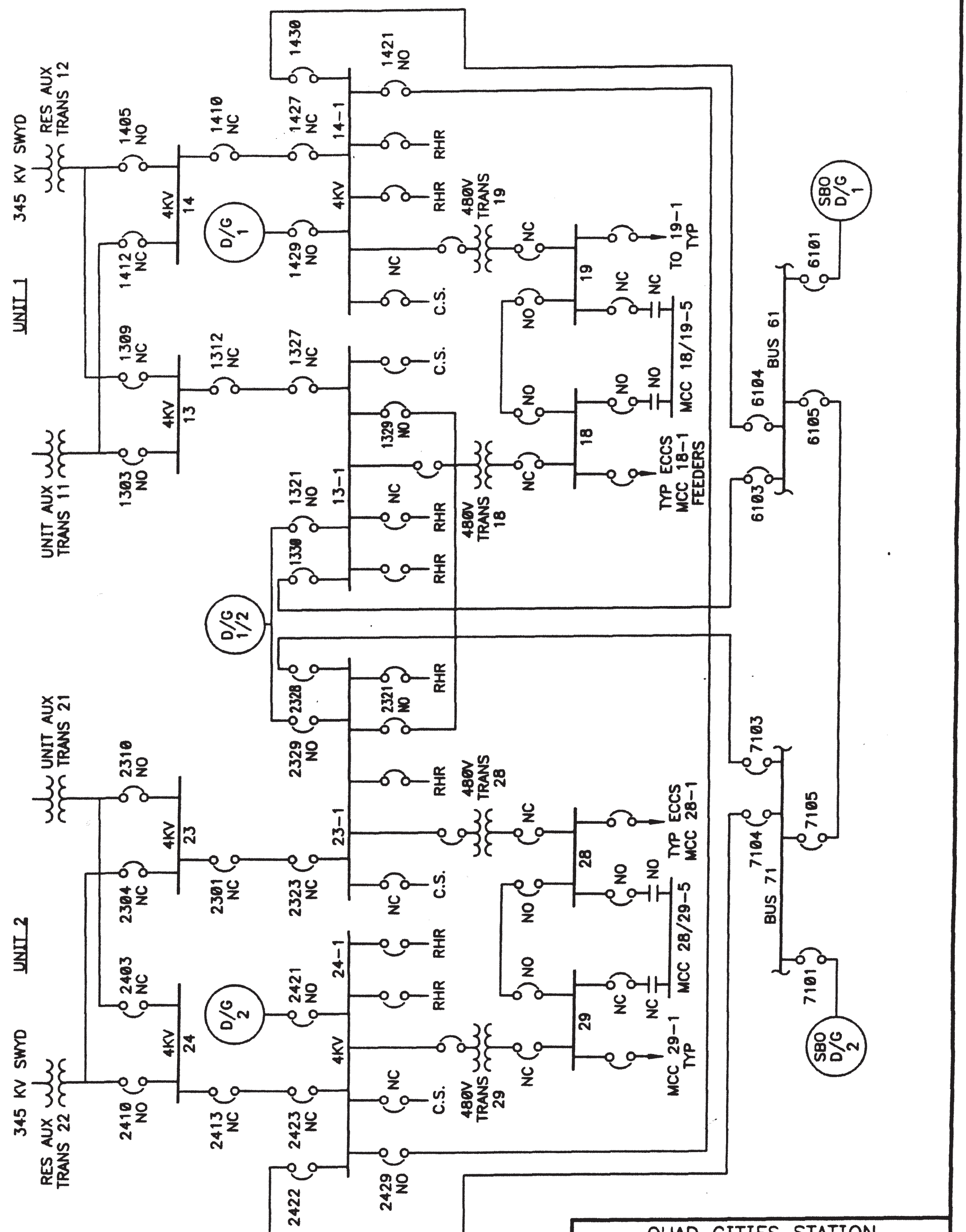
345KV TRANSMISSION SYSTEM INTERCONNECTION

FIGURE 8.2-1

REVISION 13, OCTOBER 2015



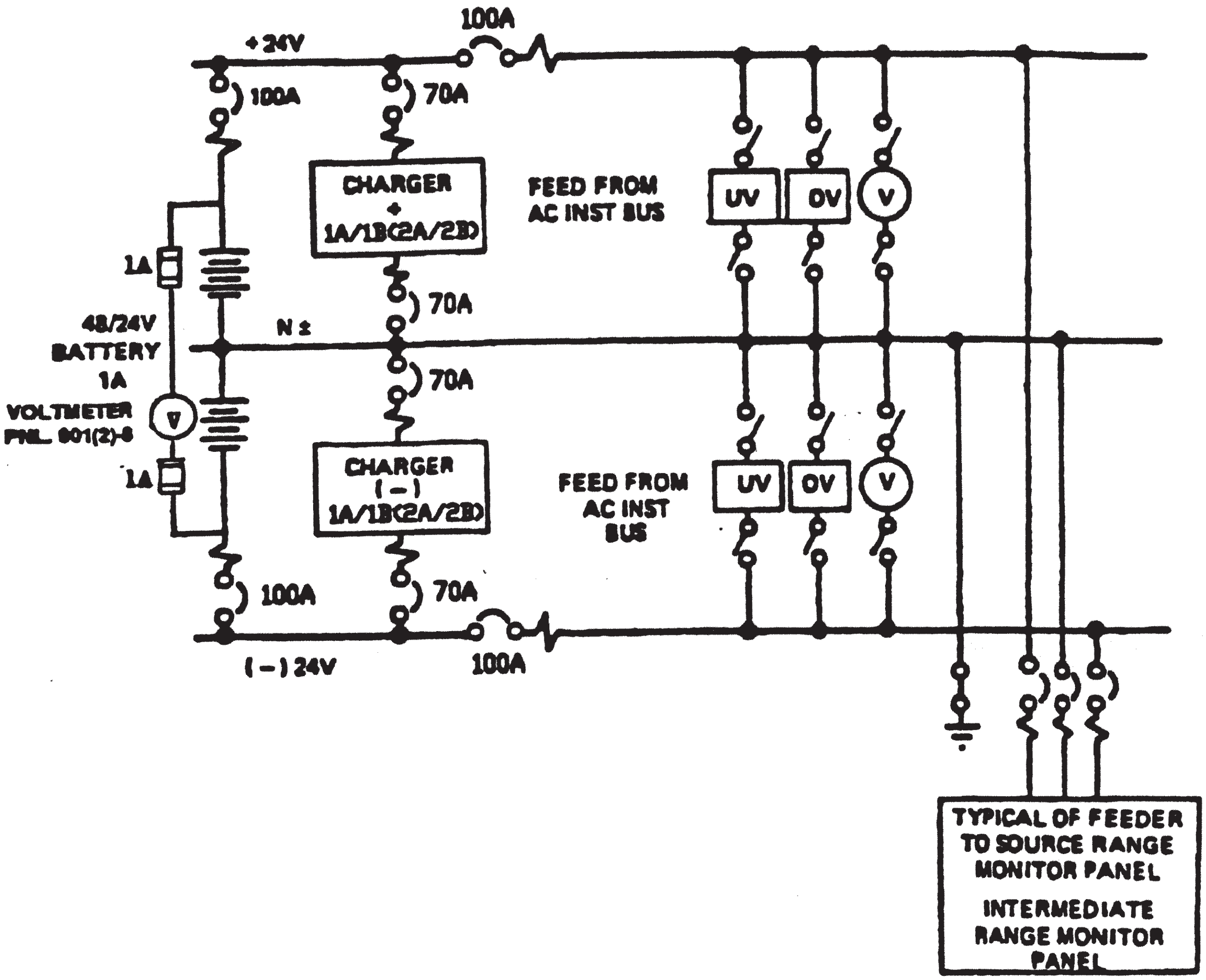
QUAD CITIES STATION UNITS 1 & 2
SINGLE LINE DIAGRAM 345KV SWITCHYARD
FIGURE 8.2-2
REVISION 13, OCTOBER 2015



QUAD CITIES STATION
UNITS 1 & 2

EMERGENCY POWER SYSTEM

FIGURE 8.3-1
REVISION 5, JUNE 1999



QUAD CITIES STATION
UNITS 1 & 2

NUCLEAR INSTRUMENT SUPPLY SYSTEM
48/24 VDC

FIGURE 8.3-2

REV. 3, DECEMBER 1995