Chapter 8: ELECTRIC POWER

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ELECTRIC POWER

8.1 INTRODUCTION

The preferred electrical power system of the Duane Arnold Energy Center (DAEC) are designed to provide redundant, diverse, and dependable power sources that are physically independent so that any failure affecting one source of supply will not propagate to alternative sources. The preferred power system provides adequate power for startup, operation, shutdown, and other plant requirements that are important to safety.

In the event of a total loss of power from the preferred source, auxiliary power will be supplied from diesel generators (standby AC power system) on the site. These power sources are physically and electrically independent from any normally connected 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 source. Loads important to plant safety are divided and connected to separate and redundant switchgear sections and means are provided for rapid detection and isolation of system faults. Electrically and physically independent battery systems serve as reliable sources of control power and perform other required tasks when AC power is not available.

8.2 OFFSITE POWER SYSTEM

8.2.1 DESCRIPTION

8.2.1.1 Power Generation Objective

The power generation objective of the DAEC switchyard is to supply power to the local transmission system (i.e., the offsite power system), which in turn supplies offsite AC power [redacted]

8.2.1.2 Power Generation Design Basis

1. The offsite power system is designed to provide a high degree of reliability.
2. The offsite power system is designed to maintain the physical independence of the offsite sources of electric power.
3. Means are provided for the detection and isolation of system faults.

8.2.1.3 System Description

The electrical output of the DAEC feeds into the local transmission system which is interconnected with neighboring transmission systems, [redacted]

8.2.1.3.1 DAEC Switchyard

The DAEC switchyard (Figure 8.2-1) is a standard electric utility design which incorporates features that provide for continuous service capabilities. Equipment can be isolated for maintenance or replacement purposes without deenergizing large sections of
2014-001 the switchyard. [redacted]

2016-015
2018-009
2017-015

[redacted]

8.2.1.3.2 Switchyard Protective Breakers and Relaying

2018-006 [redacted]

2017-015 [redacted]

2017-011

2016-011 The plant preferred AC power breakers and the generator output breakers are supervised and operated remotely from the DAEC control room. [redacted]

[redacted]

8.2.1.3.3 DAEC Transmission Lines

[redacted]

8.2.2 ANALYSIS

8.2.2.1 General

The DAEC is a single unit nuclear power station that complies with the requirements of General Design Criterion 17 of 10CFR Part 50, Appendix A. Based on DAEC review of (1) the DAEC electrical system design, (2) The related studies done for the DAEC response to (a) NRC Generic letter dated August 8, 1979 (Millstone incident, Reference 1) and (b) 10CFR50.63 (Station Blackout, Reference 3), (3) The preoperational startup tests, (4) surveillance tests, and (5) operational experience; sufficient capacity and capability of the offsite and the onsite electrical power systems exist to operate safely under all postulated events. The NRC SER issued by letter dated December 31, 1981, confirmed the adequacy of the station electric distribution system. The NRC SER issued by letter dated June 15, 1992, confirmed the adequacy of the station electric distribution system to cope with a Station Blackout. Additional studies of the plant electrical power distribution systems were completed in 1991.

[redacted]

[redacted]

A Generator Interconnection Agreement (GIA) is executed with the transmission owner and transmission operator to establish the terms and conditions for transmission of electricity generated by the DAEC to the electrical grid.

8.2.2.2 Offsite Power Grid Voltage Assessment

8.2.2.2.1 Introduction

The operation of the offsite power grid is based on recommendations and guidelines developed by the regional reliability council in conjunction with the transmission owner and the transmission operator. [redacted]

[redacted]

[redacted]

8.2.2.2.2 Grid Stability and Reliability Assessment

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Iowa has traditionally been regarded as a transiently stable region to all known operating conditions.

[redacted]

[redacted]

In accordance with the GIA, the DAEC electrical output is regulated to be consistent with the above demonstrated capabilities.

As noted earlier, the regional and local transmission operators monitor the dynamic state of the grid to assure system stability. In response to NRC concerns about grid stability, as discussed in Generic Letter 2006-02 (Reference 6), commitments were made [redacted]

[redacted]

Based on the above analysis and operating agreements, DAEC commitments to GDC-17 will not be compromised.

REFERENCES FOR SECTION 8.2

1. Letter from L. Liu, Iowa Electric, to G. Lear, Operating Reactor Branch, NRC, dated October 9, 1976 (IE-76-1590).

2. Letter from NRC to all power reactor licensees, dated August 8, 1979.

3. Letter from NRC, Docket 50-331, Station Blackout Rule Conformance Evaluation dated June 15, 1992.

4. Deleted

5. Deleted

6. Generic Letter 2006-02, “Grid Reliability and the Impact on Plant Risk and the Operability of Offsite Power,” February 1, 2006.

7. FPL Letter, L-2006-073, “NRC Generic Letter 2006-02 60-Day Response,” April 3, 2006.

8. M001-N41-071, “System Impact Study for Generation Interconnection” prepared by Midwest Independent Transmission System Operator.

9. Deleted

[redacted]

8.3 ONSITE POWER SYSTEMS

8.3.1 AC POWER SYSTEMS

8.3.1.1 <u>Auxiliary AC Power System</u>

8.3.1.1.1 Safety Objective

The safety objective of the auxiliary electric power systems is to provide, under all transient and accident conditions, reliable power required to safely shut down the reactor, to maintain the shutdown condition, and to operate all engineered safety features and auxiliaries necessary for plant safety.

8.3.1.1.2 Safety Design Bases

The auxiliary electric power systems are designed to meet the intent of the Institute of Electrical and Electronic Engineers (IEEE) Criteria for Class 1E Electrical Systems for Nuclear Power Generating Stations (Standard 308-1971).

The plant auxiliary buses supplying power to those auxiliaries and engineered safety features required for safe shutdown are designated essential buses [redacted] Each essential bus is capable of receiving power from reliable offsite sources through either the startup or standby transformers and from one of two diesel driven generators located in the plant. Each diesel generator automatically energizes its assigned essential bus on loss of offsite power. The standby diesel generators are physically and electrically independent of the offsite power source and each other, and each is capable of supplying the power required to shut down the plant and maintain it in a safe shutdown condition in the event of total loss of the normal power sources. Each power source, up to the point of its connection to the auxiliary power buses, is capable of complete and rapid isolation from any other source. The capability of the auxiliary and standby power distribution systems to meet the single failure criterion is discussed in Section 1.8, Safety Guide 6.

The power sources for the plant auxiliary power system are sufficient in number and have adequate electrical and physical independence to ensure that no single probable event could interrupt all auxiliary power at one time.

The plant layout is designed to effect physical and electrical separation of redundant bus sections, standby generators, switchgear, interconnections, feeders, load centers, motor control centers, and other system components.

Mutually redundant loads important to plant operation and safety are divided and connected to redundant switchgear sections.

8.3.1.1.3 Power Generation Objective

The power generation objective of the auxiliary electric power system is to provide a reliable source of power to operate the power auxiliaries and service systems during startup, operation, and shutdown.

8.3.1.1.4 Power Generation Design Bases

The auxiliary power system is of adequate capacity to supply the loads required to start up, operate, and shut down the plant.

8.3.1.1.5 Description

4160 V Distribution

The principal elements of the auxiliary electric power system are shown on Figure 8.3-1. [redacted]

2017-015

The standby diesel generators are the emergency sources of auxiliary AC power. [redacted]

2014-013

Each standby diesel generator also has a non-safety related start function. The generator will start upon a loss of essential bus voltage after a short time delay. The time delay allows for voltage disturbances in the switchyard to clear prior to a diesel start signal being received.

The switchgear for the 4160 V bus is of the metal-clad indoor type. Circuit breakers are three-pole and are electrically operated from 125 V plant batteries. All 4160 V breakers have stored-energy closing mechanisms. The 4160 V auxiliary buses are in four separate sections. Nonessential buses [redacted] and essential buses [redacted] are designed to meet Seismic Category I criteria.

Voltage sensors in the [redacted] monitor the essential bus voltages. Separate voltage sensors in the essential switchgear monitor the startup and the standby transformer voltages. Upon low voltage (65% or less of nominal) from the startup transformer, the safety related loads are transferred to the standby transformer. Upon low voltage from both the startup transformer and the standby transformer or a low essential bus voltage, the diesel generators are started. Upon a loss of bus voltage (24% or less of nominal), the large motors on the bus are load-shed. Upon a coincident loss of coolant accident (LOCA), some bus loads are shed and are sequentially re-energized from the standby transformer or the diesel generators.

The undervoltage sensors are chosen so that potential transients on the transmission system and bus voltage dips due to the starting of large motors will not cause a spurious transfer from the offsite power source to the onsite power source.

Degraded voltage bus protection exists for the essential 4160 V buses. When a degraded voltage condition is experienced (91.3% of nominal voltage for 8.5 seconds), the degraded voltage relays will cause the essential 4160 V incoming breakers to trip resulting in the actions discussed above.

Indicating voltmeters that monitor bus voltage and loss of voltage annunciators are provided in the control room. The plant computer alarms upon a generator overvoltage or undervoltage, a 4160 V bus undervoltage, or a startup or standby transformer undervoltage. In addition to the control room voltage monitors and alarms, indicating voltmeters are available locally in the switchgear and load centers.

2017-005 Non-safety related loss of phase ("open phase") schemes monitor the startup and standby transformer high side currents. On detection of a single- or double-open phase, the system will alarm in the control room for operator action.

<u>480 V Distribution</u>

Load center unit substations are supplied to transform power from 4160 to 480 V and to provide protection and control for 480 V feeder circuits. These units consist of an incoming bus section (4160 V), a transformer, and a low Voltage section (480 V). The transformers between the 4160 V and 480 V systems are indoor air-cooled dry type. All load center connections are inside enclosures. Each load center is in self-supporting, metal-clad sections with continuous main buses having horizontal-drawout circuit breaker units that are replaceable under live bus conditions. This equipment is properly coordinated electrically to permit safe operation under normal and short circuit conditions. Compartmentation of major components in the low voltage section confines faults, if they should occur, and provides safety for operating personnel.

The 480 V motor control centers are located in areas of electric load concentration. Those associated with the turbine-generator auxiliary systems are located [redacted] Those associated with other balance of plant equipment are located near the loads that they supply. Those associated with the nuclear steam supply system are located in Seismic Category I areas.

The 480 V motor control centers are of the indoor type, which, in addition to supplying the motors of 250 hp and below, also supply the stepdown transformers for lighting, instrumentation, and miscellaneous plant service loads.

Control and Instrumentation AC Power

Control and instrumentation power is taken from uninterruptible AC sources or the reactor protection system (RPS) AC as described below.

Instrument AC and Uninterruptible AC

The instrument AC control power is designed to provide a reliable source of 120 VAC, single phase, 60 Hz power. Continued plant operation requires that many loads supplied by this system remain operational. Reliability is achieved by using a solid state static inverter as the normal source of power with automatic transfer, via a fault sensing static switch, to a "standby" AC regulating transformer power source. A third source of power is available from the instrument AC transformer.

Instrument AC control power is supplied via two independent distribution panel [redacted] from two independent 125 VDC inverters. Each inverter has a back up 480 VAC to 120VAC regulating transformer. A third source of power is available from instrument AC transformers [redacted]

The uninterruptible AC control power system is designed to provide a reliable source of 120 VAC, single phase, 60 Hz power. Loads supplied by this system are not essential to plant safety but power interruption should be avoided. Reliability is achieved by using a solid state static inverter as the normal source of power with automatic transfer, via a fault sensing static switch, to a "standby" AC regulating transformer power source. A third source of power is available from instrument AC transformer.

Uninterruptible AC control power is supplied via distribution panel [redacted] from a single 250 VDC inverter. This inverter has a back up 480 VACA to 120 VAC regulating transformer. A third source of power is available from instrument AC transformer [redacted]

Each inverter is energized from a battery charger and supplies regulated 120 VAC power to the load. If the battery charger fails or if the 480 VAC system supplying the charger is lost, the station battery will automatically provide power to the inverter. The inverter output will stay within voltage and frequency specifications during transfer and retransfer between the two power sources (battery charger and battery). When power is restored to the battery charger, it will resume supplying the inverter and recharge the battery in both the instrument AC and uninterruptible AC control power systems. The regulating transformer is connected to the distribution panels by a solid-state static switch. The static transfer switch senses load faults, inverter over/under voltage conditions, and frequency conditions which exceed limitations, before completing an automatic transfer operation. Manual operation of the static switch allows the user to select either (inverter or regulating transformer) power source.

A separate manual transfer switch in parallel with the static switch permits maintenance on the inverter and the static switch in both the instrument AC and uninterruptible AC control power systems.

Loads supplied by this system are shown in Figure 8.3-2.

As a backup to the above system, a 480/120 VAC single phase transformer is available and can be connected to the UPS distribution panel instead of the inverter/regulating transformer system.

Reactor Protection System AC

The reactor protection system and related instrumentation are supplied from two 120 V, single-phase, 60 Hz buses. This system consists of two high-inertia M-G sets, each consisting of a three-phase induction motor driving a 120 VAC single-phase generator. Each M-G set is fed from a separate essential bus, which in turn is fed from an onsite standby diesel generator, if offsite (preferred) power supplies are not available. An alternative source of power for each RPS bus is provided from one of two regulating transformers powered from their essential 480 V bus. A manual transfer switch permits the transfer of the load from either M-G set to the alternative source when required. Interlocks are provided to prevent the powering of both RPS buses from the alternative supply simultaneously.

8.3.1.1.6 Analysis

The auxiliary power system consists of power sources, distribution equipment, instrumentation and control devices, and utilization devices.

Steady State Loads

The DAEC electrical distribution system has been analyzed to determine if the voltage levels at the safety and nonsafety buses are within the range required for proper operation of the connected utilization equipment throughout the operating range of the offsite power grid. This analysis considers the operating sequences and events given in the DAEC Nuclear Safety Operational Analysis (NSOA) which defines safety concerns and establishes the required systems to cope with events during ach plant operational state. The following operating states and events were evaluated:

Shutdown Plant electrical loads supplied while the reactor is in cold shutdown such as during refueling outages. The electrical loads will be normally supplied by the startup transformer although the main generator transformers can be used occasionally. This analysis addresses concerns of overvoltage due to lightly loaded buses.

Plant Startup Plant electrical loads are supplied by the Startup Transformer prior to synchronizing the main generator to the offsite power grid.

Full Power Normal plant operation during full reactor power. Plant safety related electrical loads are supplied by the Startup Transformer and plant nonsafety electrical loads are supplied by the station auxiliary transformer. Loading may vary due to seasonal operation of equipment and testing of equipment.

Loss of Offsite Power Electrical loads utilized in the plant response to the loss of all offsite power during full reactor power are supplied by the emergency AC diesel generators.

Loss of Coolant Accident Electrical loads utilized in the plant response to the loss of coolant accident as defined in the UFSAR during full reactor power. Plant safety related and nonsafety electrical loads are supplied by the Startup Transformer.

Loss of Coolant Accident with Loss of Offsite Power Electrical loads utilized in the plant response to the loss of coolant accident concurrent with the loss of all offsite power during full reactor power as defined in the UFSAR are supplied by the emergency AC diesel generators.

This power system analysis examines the DAEC integrated AC electrical distribution systems using models for load flow and voltage drop. The analysis techniques employed consist of Thevenin Equivalent Circuits, Superposition Theory, and graphical plotting. The power system analysis inputs are obtained from the plant controlled documentation system. The individual calculations identify these inputs and their references.

Capacity Increase / Var Compensation analyses have determined that adding switchyard capacitor banks has minimal effect on the voltage levels at the non-safety and safety related buses.

To determine the most severe service for each model, the equipment operating sequences are examined, mutually exclusive sequences identified (e.g. shutdown loads and running loads are not energized at the same time),and all credible loads are totaled to produce the highest load current flows or the largest voltage drops.

Acceptance Criteria

The applied acceptance criteria is derived from the design basis requirements for the applicable utilization system. This translates to the proper currents and voltage levels for utilization devices. Safety related motors are capable of accelerating their loads at 70%** of rated motor nameplate voltage (2800 VAC or 322 VAC). Motor operated valves are capable of required thrust at 80%* of rated nameplate voltage (368 VAC). Motor starters operate over ranges designated by manufacturer's specifications. If values beyond the range specified by the manufacturer are used for the acceptance criteria, the applicable starters are periodically tested to

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** 1VAC015A-M, RCIC Room Cooler Fan Motor, is capable of accelerating its load at 90% of rated nameplate voltage (414 VAC).

* This was an assumption for this study of the AC distribution system. Safety-related motor-operated valves are not required to have 80% terminal voltage available in order to perform their active safety functions. Refer to the Generic Letter 89-10 Program analyses for documentation of the ability of each safety-related MOV to operate under degraded voltage conditions.

verify that they will operate at or beyond the values used for acceptance. All other safety related components are designed to operate over a voltage range greater than the full range of voltages at the safety related buses. Individual calculation results are listed in plant controlled MDL documents.

Conclusions

The DAEC AC electrical distribution system has been designed, constructed and maintained in a manner that supports the design objectives and requirements for the AC support system.

All bus voltage levels meet the criteria specified above. [redacted]

Independence of Redundant Systems

All of the auxiliary power system loads required for safe and orderly shutdown and for operation of engineered safeguards are redundant and connected to separate buses, except for the MCCs which supply power for the LPCI injection valves, the reactor recirculation system isolation valves, and the MSIV leakage treatment path valves. They are tied together in a swing bus arrangement so they can be powered from either of the redundant essential divisions. Two isolation devices are provided to separate the swing bus from each essential bus and they are interlocked to prevent closing unless the redundant division source is open. Each of these breakers utilize DC control power from its own division of 125 VDC power. In the event of a loss of control power, an undervoltage device will open its breaker after a time delay, thus allowing the swing bus to transfer to the other division. This satisfies the requirements of 10 CFR 50.46 and 10 CFR 50, Appendix A, Criteria 17 and 35. The design and installation criteria that preserve the independence of redundant reactor protection systems, engineered safety features systems, and Class 1E electrical systems through physical arrangement and separation of system circuits are summarized below.

Cable Routing

Wiring for redundant channels of the reactor protection system, containment isolation systems, and engineered safeguard systems is installed in separate wire ways such that no single credible event could damage the cables of redundant counterparts of these systems. High hazard areas such as potential missile areas from sources such as rotating equipment and fire hazards such as oil storage areas have been avoided where possible. When it has been impractical to avoid missile hazard areas, a minimum separation of 20 ft or a 6-in. thick reinforced concrete wall has been provided between redundant counterparts.

In nonhazard areas, raceways containing redundant counterparts have a minimum horizontal separation of 3 ft. Vertical stacking of redundant trays has been avoided. When redundant control cables for protective functions are separated by less than 3 ft horizontally or by less than 5 ft vertically, the conductors are run in conduit only.

The spacing of wiring and components in control boards, panels, and relay racks is such as to preserve the independence of redundant channels or systems. Redundant wiring and components essential to the protection function are usually in separate panels or in panels having vertical separation barriers (e.g., reactor core cooling system vertical boards).

The main transformer, auxiliary transformer, standby transformer, startup transformer, and 345/161 KV autotransformer are outdoors and physically separated from each other. Transformers adjacent to each other are separated by fire walls to minimize their exposure to fire and mechanical damage.

Cable Separation

High voltage (4160 V) power cables are installed in raceways separate from low voltage power and control cables and from low-level instrumentation cables. High voltage power cables installed in stacked trays are, where practical, located in the highest levels of the trays. Low voltage power cables and control cables have 600 V insulation and can be in the same raceway but separate from high voltage power and low-level instrumentation cables.

Low-level instrumentation cables are installed in separate steel conduits or in separate nonventilated trays with covers to provide adequate electromagnetic shielding. The tray containing instrumentation cables occupies the lowest level in a stack.

The minimum vertical distance between stacked trays is 1 ft from the bottom of the upper tray to the top rail of the lower tray. The separation criteria based on the voltage and power level of the electrical circuits are in addition to the separation criteria based on redundancy requirements.

Raceway Sharing

The sharing of raceways by engineered safety features cables and nonsafeguard cables is permitted if such sharing is limited to a single separation division raceway (i.e., a single nonsafeguard cable is not allowed to be run in the raceways of two independent safeguard divisions). RPS cables are required to be in conduits used for no other wiring. Nonsafeguard cables in proximity to safeguard cables have identical application design criteria and manufacturing specifications to that specified for safety-related cables for similar service in similar ambient conditions. Nonsafeguard cables with commercial specifications (e.g., lighting, communications, specialty) are routed separately in their own nonscheduled raceway.

Different plant parameter signals (instrument and control) have been run in the same raceways, including trays, junction boxes, and conduits, provided that (1) the sensors of the different parameters belong to the same instrument channel in the case of the reactor protection system; or (2) the sensors are associated with plant monitoring that has no reactor protection, primary containment isolation, or engineered safeguards function.

Identification

Equipment items, raceway and cabling are labeled with markers which allows the identification of the classification of the component, including the safety division of the equipment. Similarly, if a panel or rack contains equipment associated with more than one channel or division, the equipment is permanently tagged to indicate the appropriate channel or division. Unique groups of letters and numbers have been assigned to the reactor protection system, primary containment isolation system, and engineered safety features cabling systems to assist in implementing separation criteria.

Containment Penetrations

Electrical penetrations have been provided in two penetration areas on opposite sides of the primary containment. Each penetration area contains penetrations for equipment of one division of the engineered safeguards system, one division of the primary containment isolation system, and two divisions (1 and 3 or 2 and 4) of the reactor protection system to ensure maximum separation of these functions. These two divisions of the reactor protection system have been arranged to ensure the maximum possible separation within the same penetration area for each redundant function.

Separate penetration assemblies, grouped functionally, have been provided for high Voltage (4160 V) power cables, low voltage power and control cables, shielded instrumentation cables, and thermocouple cables.

Overload and Short Circuit Considerations

Power cables are sized to carry design load currents and fault currents with conductor temperatures remaining within the limits established by the wire and cable manufacturer to obtain full expected cable life. Power cables have been selected with ratings satisfying IPCEA ampacity values as a minimum requirement. Protecting circuit breakers or starter overload heaters have long time trip settings that adequately protect the cables on sustained overloads or on overloads that would exceed the cable rating or cause harmful overheating of the insulation. The maximum current-interrupting ratings of the circuit breakers exceed the maximum available short circuit current.

Tray fill has generally been limited to 40% by cross section. Tray fill greater than 40% by cross section has been carefully reviewed to ensure that cable thermal damage will not take place. Large-diameter cables, where the fill may exceed 30%, have been installed in a single cable layer.

Conservative rating of cables and adequate derating to cover higher ambient temperatures and proximity effects of current-carrying cable in the same wireway ensure that an adequate margin will always exist between the actual conductor temperatures and the maximum allowable safe conductor temperatures.

In areas where ambient temperatures above 40°C are encountered, procedures outlined by IPCEA have been used to further derate the cables. Cables installed in exposed conduit and nonventilated trays are thermally sized in accordance with IPCEA ampacity values of three identical single-conductor cables in isolated conduit in 40°C air. The cables have been derated as above for more than three single-conductor cables or more than one three-conductor cable in the raceway and for ambient temperatures exceeding 40°C.

Special Considerations

Solid covers are provided on each top tray run under stairways and gratings and in open areas where cable damage from falling objects or collection of dirt and debris is likely. Vertical trays are provided with solid covers a minimum of 6 ft above each floor penetration. The trays have been manufactured and tested in compliance with the NEMA Cable Tray Standards.

The design for cable trays and supports has been established to meet Seismic Category I requirements for tray loading. In addition, a single 200-lb live load anywhere along the tray span between the tray supports was added for static analysis.

For those trays to which fire protection material has been added, the dynamic loading (seismic event) design has been analyzed for the added weight of the fire protection material.

Loss of Auxiliary Nonessential Power.

Auxiliary power that supplies nonessential buses only is normally supplied by the auxiliary transformer, with the startup transformer as backup. It is improbable that both electric power sources would be lost simultaneously, because each is supplied from a different source. On loss of auxiliary transformer output, detected by undervoltage relays on buses [redacted] there will be an automatic transfer of these buses to the startup transformer if its undervoltage relays indicate available voltage.

Inspection and Testing.

Inspections and tests at vendor factories and during startup have demonstrated that the design and construction of the auxiliary AC systems have been properly implemented.

Operational testing of the normal and standby power systems is conducted under conditions that simulate the loss of offsite power. This testing demonstrates the following:

All essential loads can be operated in the proper sequence for each design-basis accident condition with normal power available for essential loads.

The relaying and control system can detect a loss of external power and, with the buses dead, start and load the standby power sources.

The standby power sources can provide sufficient power for an adequate time interval.

Each essential AC power circuit breaker shall be subject to inspection and preventive maintenance in accordance with procedures based on the manufacturer’s recommendations and industry experience.

8.3.1.2 Standby AC Power System

8.3.1.2.1 Safety Objective

The safety objective of the standby AC power supply and distribution system is to provide power required to safely shutdown the plant and to protect against postulated accidents in the event of the loss of offsite power.

8.3.1.2.2 Safety Design Bases

The standby AC power supply consists of two separate divisions, each with a diesel-driven generator, essential 4160 V and 480 V buses, motor control centers, and a DC control power source. The two divisions are electrically and physically independent to ensure that no single event can cause the loss of both.

On a reactor low-low-low water level, drywell high pressure, loss of offsite power, or a degraded voltage condition, both diesel generators start automatically. When each diesel generator reaches operating voltage and frequency and there is no voltage on the corresponding emergency service bus, the diesel generator is automatically connected to its bus. To prevent an initial overload of the diesel generators, their selected loads are started in sequence. This loading sequence has been designed to provide maximum core cooling flow in the shortest practicable time.

Each diesel engine has two independent starting air supply systems. Each starting air supply system has the capability of providing a minimum of five normal diesel starts per air receiver without recharging. A minimum of fifteen normal diesel starts are provided for each diesel engine. If the air start receivers are depleted and the normal air supply for recharging is not available, procedures and permanently installed emergency diesel driven compressors are available to directly recharge the receivers.

The fuel supply for the engines consists of one common underground fuel storage tank and a day tank for each engine. The diesel fuel storage tank is of sufficient capacity to meet the diesel generator fuel requirements for approximately 7 days. The day tank capacity meets the fuel requirement for approximately 4 hours.

The diesel generators are equipped for periodic manual starting to permit tests for readiness. In addition, load carrying capability may be demonstrated without interruption of normal plant operation.

8.3.1.2.3 Description of Standby AC Power Systems

Emergency AC System

The prime movers for the Emergency AC Power System are two identical 12 cylinder, opposed piston, turbo-charged diesel engines.

The generators for the Standby AC Power System are two identical synchronous alternators operating at 4160 Volts, 60 cycles. Each diesel generator has a continuous rating of 2850 KW, a 2000-hr rating of 3000 KW, and a 300-hr rating of 3250 KW. The generator is a grounded "wye"-configured source.

The auxiliary systems for the DAEC diesel generators are described in the following sections.

Fuel oil supply system. (Section 9.5.4)
Diesel generator cooling water system. (Section 9.5.5)
Air starting system. (Section 9.5.6)
Auto lube oil makeup system. (Section 9.5.7)
Combustion air intake and exhaust system. (Section 9.5.8)
Room ventilation system. (Section 9.5.8)

The standby diesel generators produce AC power at a voltage and frequency compatible with the normal bus requirements for essential equipment within the plant. Each diesel generator has sufficient capacity to start and carry the loads required to shut down the plant and maintain it in a safe shutdown condition.
Each of the diesel generators supplies standby power to a separate 4160 V bus, as shown in Figure 8.3-1.

The loads supplied by the standby diesel generator system are grouped into two main categories, as follows:

1. Loads required immediately.

2. Loads required for orderly shutdown without offsite power and may be time sequenced.

The location of all equipment within the diesel generator rooms, including air compressors, air receivers, day tanks, lube oil makeup tanks, control panels, and diesel generators, is shown in Figure 1.2-4. This figure also shows the position of the diesel generator rooms in the plant.

<u>TSC/PPC Standby Generator</u>

A 350 KW diesel generator provides reliable standby AC power for the plant process computer (PPC) and the technical support center (TSC). This diesel generator unit, which is not safety related, starts automatically on loss of power to either the LLRPSF transformer, [redacted], or the site support substation transformer, [redacted], (see Figure 8.2-1). Automatic transfer switches then supply power from the diesel generator to the TSC and PPC, the PBX telephone power distribution system and the CARDOX fire suppression power supply.

2017-009 The TSC/PPC standby diesel generator unit consists of a skid-mounted, six cylinder diesel engine and a 350 KW, 480 VAC generator in a weatherproof, sound attenuated enclosure. The unit and its dedicated 693 gallon fuel tank are located in the yard, north of the turbine building. Actual useable capacity of the fuel tank is 670 gallons. The fuel tank is integral within the generator set's base frame.

8.3.1.3 Analysis

On a reactor low-low-low water level, high drywell pressure signal, loss of offsite power, or a degraded voltage, the following events take place automatically.

The standby diesel generators are automatically started.

If there has been a loss of normal offsite auxiliary power sources, the normal power source breakers on the emergency service switchgear automatically trip open. All 4160 V feeder breakers on the emergency service buses are tripped open, except for the feeds to the emergency service 480 V load centers.

When the voltage on an emergency service bus is established from the diesel generator, some essential loads are started immediately and others are automatically started in a predetermined sequence. Manual operation from the plant main control room is available for other auxiliaries on the essential buses. Automatic functions are monitored in the main control room, permitting the operator to observe that proper conditions have been established.

Table 8.3-1 describes the loading sequence of loads onto the onsite power (diesel) supply, along with the corresponding voltage and frequency responses, during a post-LOCA period to prevent core damage and enable containment heat removal to begin. (Note: The loads and responses are the original design values. Loads are design controlled and periodically analyzed to ensure that they remain at or below the total loads shown for each elapsed time sequence shown.) Studies have been performed (Section 15.2.1) that demonstrate that margin is available to relax these performance requirements while still meeting the acceptance criteria of 10CFR50.46. The table indicates the total capacity required for the operation of equipment necessary for core and containment cooling during the post-LOCA period will be below the rated load capability of the diesel generators.

The sequence described in Table 8.3-1 is adjusted to 5-sec (nominal) intervals to permit each sequence group of motors to obtain operating speed before the application of the next sequence group. The total load in each sequence group is selected to prevent a voltage or frequency dip that would cause relays or contactors to drop out or motors to pull out or stall.

The diesel generator is designed such that an instantaneous loss of load up to the continuous rating of 2850 KW will not result in an overspeed trip of the diesel.

The excitation system of the diesel driven generators uses an ungrounded, open-delta-excitation, primary-side potential transformer configuration. There is no circuit connecting the generator ground and the exciter primary transformer. By design, this system will only pass low frequencies from phase to phase, and these frequencies will cancel each other out. Therefore, low frequency harmonics present in the system will cancel without producing undesirable high-circulating currents that could damage the exciter primary transformer.

The separation of the diesel generators to meet the single failure criterion is illustrated in Figure 1.2-4. Isolation is accomplished by locating the diesel generators in separate rooms and by ensuring that all control and support equipment for each diesel generator is separate and redundant. The electrical isolation of the diesel generators is shown in Figure 8.3-1.

Components of the diesel generators and support systems are located so as to minimize the possibility of damage due to explosions or missiles. Redundant components are protected from each other and from common failure due to any single explosion or missile through
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Protection against seismic events is provided by designing all critical components of the diesel generators and support systems to withstand a design basis earthquake. The plant seismic design is discussed in Chapter 3.

The diesel generators and their auxiliary equipment are designed for approximately 7 days of unassisted operation. To ensure unassisted diesel generator operation, the following design features are provided:

Automatic recharging of the air starting compressed air tanks to permit starting and stopping the diesel generators during the period of required extended operation.

Adequate fuel storage for the continuous operation of one diesel generator for approximately 7 days, and automatic fuel transfer to that diesel generator.

Automatic lube oil makeup to the diesel crankcase for at least 7 days of continuous operation.

In the event that the diesel generator rooms are inaccessible, the diesel generators can be operated from the main control room.

[redacted]

[redacted]

[redacted]

In the case of plant shutdown from outside the control room due to fire, [redacted]

8.3.1.4 <u>Inspection and Testing</u>

Readiness of the diesel generators is demonstrated by periodic testing, which simulates actual emergency conditions insofar as practical. The testing program is designed to confirm the diesel generator's ability to start as well as to run under load for a period of time long enough to reach equilibrium conditions to ensure 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.

The preoperational test program for the emergency diesel generators is discussed in the response to Safety Guide 9 in Section 1.8.

A test program was conducted increasing the load beyond the initial load increment and reducing the load sequence time intervals shown in Table 8.3-1. The object of these tests was to determine that adequate margin is included in the design.

The initial test was run with the loads and intervals indicated in Table 8.3-1. The voltage, frequency, and load time increments were recorded and used as a base for a following series of tests. In the series of tests that followed, the load was increased beyond the initial load increment and the load sequence test was repeated. The results of this test were compared to the base with respect to the load response interval times. From the resulting data, shorter load interval times were determined and the test was repeated. The load interval times were reduced and the test was continued until it was determined that the voltage and frequency perturbations did, in fact, degrade the ability of the system to pick up the designated loads in accordance with Table 8.3-1. The results of this series of tests were analyzed to determine the margin inherent in the design.

The frequency does not return to within at least 2% of nominal within 40% of the load sequence time interval as required by Safety Guide 9 acceptable limits. However, it is concluded from the above that the recovery time shown in Table 8.3-1 has no detrimental effect on system reliability or performance. (See Section 1.8, Safety Guide 9.)

Surveillance requirements are presented in the Technical Specifications for the diesel generators and their support equipment. In addition to the Technical Specifications' surveillance requirements, the diesel generators and their auxiliary equipment are subject to inspection and preventive maintenance in accordance with procedures based on the manufacturer’s recommendations and industry experience. This ensures the availability of the diesel generators for periods of reliable, extended operation. During the monthly start test the emergency diesel generator starting air compressors shall be checked for operation and their ability to recharge air receivers.

A Plant Modification has been performed on the diesel generators which automates the slow start sequence for surveillance testing but bypasses this logic making the unit available for emergency service if required.

8.3.2 DC POWER SYSTEMS

8.3.2.1 Description

8.3.2.1.1 Safety Objective

The safety objective of the DC power supply and distribution system is to provide a source of reliable, continuous power for the control and instrumentation of safeguard systems and for other loads required for normal operation and orderly shutdown.

8.3.2.1.2 Safety Design Bases

The plant essential DC power supply system consists of two 125 V batteries, one 250 V battery, and two plus and minus 24 V batteries, each system with its own charger. The plant battery systems (125 V and 250 V) are sized to supply, without recharging, the control and essential instrumentation power for a minimum of 4 hours and the emergency motor loads for their required length of time.

Each battery charger is sized to restore its battery to full charge after a 4-hr emergency discharge while carrying normal steady state dc loads. Each charger receives AC power from a separate AC bus. One spare battery charger is supplied for either of the two 125 V batteries, and one spare charger is provided for the 250 V battery.

The plant battery systems are arranged so that no single circuit component failure will prevent the combined systems from providing power to vital functions. The Division I and Division II batteries, chargers, and distribution panels are in separate Seismic Category I rooms.

8.3.2.1.3 Description of DC Power Systems

8.3.2.1.3.1 250 V System

One 250 V battery with two redundant full-capacity battery chargers is provided for heavy motor loads. Two 250 V motor control centers are provided, one of which is used for the high pressure coolant injection (HPCI) system and the other for containment isolation valves. The 250 V battery and dc distribution system are treated as a Division II system with divisional separation requirements applied.

Annunciators and computer logging are provided in the control room to alert the operator whenever the 250 V battery system has abnormal conditions.

8.3.2.1.3.2 125 V System

Two separate 125 V plant batteries are furnished, each with its own static-type battery charger, circuit breakers, and bus. One spare battery charger is provided that can be connected to either of the two batteries for servicing and as a backup to the normal power supply charger.

Four separate 125 VDC power panel boards are provided, two powered from one 125 V bus and two from the other. To maintain separation in the divisional essential systems, the dc control power that is provided to each redundant AC bus or group of essential equipment comes from different 125 V batteries. One battery is used to furnish power to the reactor core isolation cooling motor control center.

Annunciators and computer logging are provided in the control room to alert the operator whenever a 125 V battery system has abnormal conditions.

8.3.2.1.3.3 24 V System

Two independent plus and minus 24 V system buses are provided, each supplied by a center-tapped 48 V battery and two 24 V battery chargers that are fed from essential AC buses.

The systems are redundant, with each having its own 24-cell battery, two battery chargers, and a distribution panel. Separation is provided for all equipment and feeders as in all other safeguards systems.

Each plus and minus 24 VDC bus supplies Source and Intermediate range core activity monitors and liquid process radiation monitors.

8.3.2.2 Analysis

8.3.2.2.1 General

All of the normal loads connected to the plant battery system can be supplied by the battery chargers. The chargers can be powered from multiple sources of plant auxiliary power including the plant standby diesel generator system. The aggregate system is so arranged and powered that the probability of system failure resulting in a loss of DC power is very low. The system vital components are either self-alarming on failure, or provisions are made for periodic inservice testing to detect faults. Only the motor loads require the capacity of the storage battery for their operation.

The effect of a single DC power supply failure on emergency core cooling system performance has been reviewed by the NRC as documented in References 3, 6 and 7. The NRC has concluded that emergency core cooling system performance with a DC power supply failure is acceptable. The DAEC emergency core cooling system is discussed in Section 6.3.

Each 125 V and 250 V battery is located in a separately ventilated room of the control building. The battery racks meet the requirements for earthquake design. The 125 V and 250

VDC systems operate ungrounded with a ground detector alarm in the main control room set to annunciate a ground fault. Thus, multiple grounding, which is the only reasonable mode of failure and which usually affects only one circuit, is extremely unlikely. The normal mode of battery failure is the deterioration of a single cell. Such a failure is signaled well in advance by the routine tests performed on the battery.

The consideration of the consequences of ventilation system failure is discussed in the Technical Requirements Manual.

8.3.2.2.2 Loss of 250 V Battery

The 250 V battery supplies power for the HPCI turbine oil pump and other auxiliaries. A loss of the 250 V battery would thus prevent operation of the HPCI system. The HPCI system is redundant in its core cooling function with the automatic depressurization system that does not require 250 VDC for operation. All of the 250 VDC motor-operated isolation valves have redundant counterparts that do not rely on DC power. A loss of the 250 V system would be annunciated and would permit troubleshooting of the system. The uninterruptible AC inverter is also powered from the 250 V battery if the 250 VDC battery charger fails or if a loss of the 480 VAC system supplying the charger occurs. Alternate sources for the uninterruptible AC power system are discussed in Section 8.3.1.1.5.

8.3.2.2.3 Loss of 125 V Battery

The 125 V batteries are well protected from an electrical as well as a physical standpoint; however, it is assumed that one of the batteries or its bus system could malfunction. Equipment operated by DC power that is vital to plant safety is arranged so that the failure of one of the batteries would not prevent accomplishing the desired action. The safeguard systems using dc power are redundant in themselves and are supplied from separate 125 V buses. All system components are annunciated or are arranged to facilitate periodic testing while in service. Because of this redundancy, it is concluded that a loss of a battery or its bus would not be of serious consequence although it might cause an operating inconvenience.

8.3.2.2.4 Loss of 24 V Battery

The 24 VDC system provides power for source range monitoring, intermediate range monitoring, and liquid and gaseous process radiation monitoring. The two neutron monitoring functions are required for safety; however, the design is fail-safe in that loss of 24 VDC power would cause the associated trip to function.

8.3.2.3 <u>Inspection and Testing</u>

The plant batteries and other equipment associated with the dc system are easily accessible for inspection and testing. Service and testing are accomplished on a routine basis. The frequency and scope of maintenance and inspections are in accordance with normal plant practices, manufacturer's recommendations and operating history. Typical inspections include visual inspections for leaks and corrosion and the testing of all batteries for voltage, specific gravity, and level of electrolyte.

8.3.3 FIRE PROTECTION FOR CABLE SYSTEMS

Fire protection considerations include insulation flame resistance and the ability to maintain circuit integrity, including design load current capability, at elevated ambient temperatures resulting from a design basis accident. All cables prior to December 1, 1977, were required to pass the IPCEA flame-resistance tests in accordance with IPCEA Standards S-19-81, Section 6.19.6, and S-61-402, Section 6.5. The cables were also subjected to the following flame-resistance tests:

1. Horizontal and vertical tray configuration exposure to sustained flame with Fisher burner.

2. Vertical tray cable fire propagation test.

3. Horizontal bonfire test (600 V power and control cables only).

All cables procured after December 1, 1977, shall pass flame resistance tests in accordance with ICEA Standard S-19-81, Section 6.19.6. Power, control, and single pair thermocouple extension cables procured after December 1, 1977, shall pass flame tests in accordance with IEEE Standard 383-1974, Sections 2.5.1 through 2.5.5.

All cables procured after December 1, 1977, are not required to pass the three flame resistance tests listed above or the ICEA Standard S-61-402, Section 6.5, flame-resisting test, since these tests are less stringent than the newer flame tests.

All openings in floors and ceilings for the vertical ventilated tray installation are provided with fire stops. Similarly, all openings for cable runs into the control room, control equipment, switchgear, load centers, motor control centers, etc., are sealed with fire-resistant material.

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As part of initial construction, all cables in trays in the control room back panel area, exterior to the control panels, (upper cable spreading room) have been coated with Flamemastic 77, on top and bottom, to a wet thickness of 1/8 in. Flamemastic 77 is a fire-retardant compound utilized in the control room back panel area to retard the propagation of cable fires.

Because of the installation of the Alternate Shutdown Capability System (ASCS) and improvements in the fire retardant properties of cables, coating of cables in this area is not required. The DAEC ASCS is described in Section 7.4.2

REFERENCES FOR SECTION 8.3

1. Letter from L. D. Root, Iowa Electric, to J. G. Keppler, NRC, Subject: Loss of Non-Class 1E Instrumentation and Control Power System Bus During Operation, dated February 28, 1980.

2. Letter from D. L. Mineck, Iowa Electric, to L. Clardy, NRC, Subject: Evaluation of Class 1E Switchgear "Close" Circuits, dated June 21, 1983.

3. Letter from D. B. Vassallo, NRC, to L. Liu, Iowa Electric, Subject: Effect of a DC Power Supply Failure on ECCS Performance, dated October 24, 1983.

4. Letter from W. D. Shafer, NRC, to L. Liu, Iowa Electric, Subject: NRC Inspection Report 50-331/86020, dated February 6, 1987.

5. Letter from R. W. McGaughy, Iowa Electric, to A. B. Davis, NRC, Subject: Response to Request for Additional Information Regarding Our Response to NRC Inspection Report 50-331/86020, ERF Appraisal, dated June 10, 1987 (NG-87-1630).

6. Letter from J. R. Hall, NRC, to L. Liu, Iowa Electric, Subject: Transmittal of SER for LPCI Swing Bus Design Modification, dated January 19, 1989.

7. Letter from D. L. Mineck, Iowa Electric, to T. E. Murley, NRC, Subject: Consideration of Postulated Electrical Failure in 10CFR50.46 ECCS Analysis, dated June 26, 1989.

8. Deleted.

Table 8.3-1 (Page 1 of 2)
SINGLE DIESEL-GENERATOR LOADING SEQUENCE AND RESPONSE - LOSS-OF-COOLANT ACCIDENT PLUS LOSS OF OFFSITE POWER[a]

Elapsed Time from Initiation of Event	Load Increment (kW)[e]	Total Load (kW)[d]	Voltage (% of rated)	Recovery Time to 90% Rated Voltage (sec)	Frequency (% of rated)	Recovery Time to 98% Rated Frequency(sec)	Description
0 SEC							LOCA ACCIDENT
3 SEC							LOW REACTOR WATER LEVEL OR HIGH DRYWELL PRESSURE SIGNAL, EDG START SIGNAL
13 SEC			100		100		EDG CLOSES TO BUS, SIGNAL REACTOR RECIRC AND CONTAINMENT ISOLATION, LPCI AND CORE SPRAY INJECT VALVES OPEN
	13.0						MCC [redacted] LOADS
	135.0						MCC [redacted] LOADS SYSTEM LOSSES AND CHILLER AUX LOADS.
	345.1						MCC [redacted] LOADS & [redacted]
	114.0						MCC [redacted] LOADS
	104.0	711.1	≥73	≤1.2	≥96.7	≤3.07	RIVER WATER SUPPLY PUMP START[b]
18 SEC	612	1323.1	≥80	≤1.3	≥97.2	≤3.91	CORE SPRAY PUMP START
21 SEC							CORE SPRAY INJECT VALVE OPEN

Table 8.3-1 (Page 2 of 2)
SINGLE DIESEL-GENERATOR LOADING SEQUENCE AND RESPONSE -
LOSS-OF-COOLANT ACCIDENT PLUS LOSS OF OFFSITE POWER[a]

23 SEC	496	1819.1	≥80	≤1.3	≥97.2	≤3.91	FIRST RHR (LPCI) PUMP START
28 SEC	496	2315.1	≥83	≤1.1	≥97.1	≤2.45	SECOND RHR (LPCI) PUMP START
31 SEC							LPCI VALVES OPEN
43 SEC							REACTOR RECIRC VALVES CLOSE, COMPLETION OF LPCI SEQUENCE
After 10 min [c]	66	2381.1	--	--	--	--	CONTROL BUILDING CHILLER START[f]
	-162	2219.1	--	--	--	--	MCC LOAD REDUCTION
	-496	1723.1	--	--	--	--	TRIP RHR PUMP
	470	2193.1	--	--	--	--	RHR SERVICE WATER PUMP START
	470	2663.1					RHR SERVIE WATER PUMP START

NOTE: [a] See Section 15.3.1 for actual safety analysis assumptions.

[b] If the RWS pump selected for auto start was running prior to the LOOP, the selected RWS pump will trip and will restart 120 seconds after the diesel generator output breaker closes.

[c] Additional loads may be applied at operator's discretion.

[d] Present loads are less than original design loads listed for all total loads. Thus the frequency and voltage responses should be equal to or better than the original design responses listed.

[e] Original Design Loads

[f] Original CB Chiller Start was shown at 73 seconds, which is incorrect. Corrected to After 10 minutes.