C.I.8. Electric Power

The electric power system is the source of power for station auxiliaries during normal operation, and for the protection system and engineered safety features during abnormal and accident conditions. Thus, the information in Chapter 8 of the final safety analysis report (FSAR) should be directed toward establishing the functional adequacy of the safety-related electric power systems (and electrical systems important to safety) and ensuring that these systems have adequate redundancy, independence, and testability in conformance with the current criteria established by the U.S. Nuclear Regulatory Commission (NRC).

C.I.8.1 *Introduction*

In this section, the applicant should provide a brief description of the utility grid and its interconnection to the nuclear unit and other grid interconnections. In addition, the applicant should briefly describe the onsite electric system in general terms, as well as the alternative alternating current (AAC) power source provided to mitigate station blackout (SBO) and the associated interconnections to safety buses. This description should identify the safety loads (i.e., the systems and devices that require electric power to perform their safety functions), the safety functions performed (e.g., emergency core cooling, containment cooling), and the type of electric power (ac or dc) required by each safety load.

In addition, the applicant should present and discuss the design bases, criteria, regulatory guides, standards, and other documents that will be implemented in the design of the safety-related electric systems and electrical systems important to safety. In so doing, the applicant should describe (and provide a positive statement regarding) the extent to which the design conforms with the recommendations of the following NRC regulatory guides, branch technical positions, and generic letters, as well as the following standards promulgated by the Institute of Electrical and Electronics Engineers (IEEE):

- Regulatory Guides:

  Regulatory Guide 1.6, "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems" (Safety Guide 6)

  Regulatory Guide 1.9, "Selection, Design, Qualification, and Testing of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants"

  Regulatory Guide 1.22, "Periodic Testing of Protection System Actuation Functions"

  Regulatory Guide 1.30, "Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment" (Safety Guide 30)

  Regulatory Guide 1.32, "Criteria for Power Systems for Nuclear Power Plants"

  Regulatory Guide 1.29, "Seismic Design Classification"

  Regulatory Guide 1.40, "Qualification Tests of Continuous-Duty Motors Installed Inside the Containment of Water-Cooled Nuclear Power Plants"

  Regulatory Guide 1.41, "Preoperational Testing of Redundant On-Site Electric Power Systems To Verify Proper Load Group Assignments"

  Regulatory Guide 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems"

Regulatory Guide 1.53, "Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems"

Regulatory Guide 1.62, "Manual Initiation of Protective Actions"

Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants"

Regulatory Guide 1.73, "Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants"

Regulatory Guide 1.75, "Physical Independence of Electric Systems"

Regulatory Guide 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants"

Regulatory Guide 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants"

Regulatory Guide 1.93, "Availability of Electric Power Sources"

Regulatory Guide 1.100 , "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants"

Regulatory Guide 1.106, "Thermal Overload Protection for Electric Motors on Motor-Operated Valves"

Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems"

Regulatory Guide 1.128, "Installation Design and Installation of Large Lead Storage Batteries for Nuclear Power Plants"

Regulatory Guide 1.129, "Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Nuclear Power Plants"

Regulatory Guide 1.131, "Qualification Tests of Electric Cables, Field Splices, and Connections for Light-Water-Cooled Nuclear Power Plants"

Regulatory Guide 1.153, "Criteria for Safety Systems"

Regulatory Guide 1.155, "Station Blackout"

Regulatory Guide 1.156, "Environmental Qualification of Connection Assemblies for Nuclear Power Plants"

Regulatory Guide 1.158, "Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants"

Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"

Regulatory Guide 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems"

Regulatory Guide 1.204, "Guidelines for Lightning Protection of Nuclear Power Plants"

- Branch Technical Positions (BTPs):

  Branch Technical Position ICSB 2 (PSB), "Diesel Generator Reliability Qualification Testing"

  Branch Technical Position ICSB 8 (PSB), "Use of Diesel Generator Sets for Peaking"

  Branch Technical Position ICSB 11 (PSB), "Stability of Offsite Power"

  Branch Technical Position ICSB 18 (PSB), "Application of Single Failure Criterion to Manually Controlled Electrically Operated Valves"

  Branch Technical Position PSB 1, "Adequacy of Station Electric Distribution System Voltages"

  Branch Technical Position PSB 2, "Criteria For Alarms and Indications Associated With Diesel Generator Unit Bypassed and inoperable Status"

- Generic Letters:

  Generic Letter 77-07, "Reliability of Standby Diesel Generator Units"

  Generic Letter 79-17, " Reliability of Onsite Diesel Generators at Light-Water Reactors"

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

  Generic Letter 88-15, "Electric Power Systems: Inadequate Control Over Design Process"

  Generic Letter 91-11, "Resolution of Generic Issues 48, 'LCOs for Class 1E Vital Instrument Buses,' and 49, 'Interlocks and LCOs for Class 1E Tie Breakers," Pursuant to 10 CFR 50.54'"

  Generic Letter 94-01, "Removal of Accelerated Testing and Special Reporting Requirements for Emergency Diesel Generators"

  Generic Letter 96-01, "Testing of Safety-Related Circuits"

  Generic Letter 2006-02, "Grid Reliability and the Impact on Plant Risk and the Operability of Offsite Power"

- IEEE Standards:

  IEEE Std 308, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations"

  IEEE Std 317, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations"

  IEEE Std 338, "Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems"

  IEEE Std 379-1972, "IEEE Trial-Use Guide for the Application of Single-Failure Criterion to Nuclear Power Generating Station Protection Systems"

IEEE Std 384, “IEEE Trial-Use Standard Criteria for Separation of Class IE Equipment and Circuits”

IEEE Std 387, “IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Onsite Electric Power Systems at Nuclear Power Generating Stations”

IEEE Std 450, “IEEE Recommended Practice for Maintenance, Testing and Replacement of Large Lead Storage Batteries for Generating Stations and Substations”

IEEE Std 484, “IEEE Recommended Practice for Installation, Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations”

IEEE Std 519, “IEEE Recommended Practices and Requirements for Control in Electrical Power Systems”

IEEE Std 535, “IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Systems”

IEEE Std 603, “Criteria for Control Portions of Safety Systems Safety Systems for Nuclear Power Generating Stations”

IEEE Std 665, “IEEE Guide for Generating Station Grounding”

IEEE Std 666, “IEEE Design Guide for Electrical Power Service Systems for Generating Stations”

IEEE Std 741,”Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations”

IEEE Std 1050, “IEEE guide for Instrumentation and Control Equipment Grounding in Generating Stations”

IEEE Std C62.23, “IEEE Application Guide for Surge Protection of Electric Generating Plants”

Wherever alternative approaches are used, demonstrate that an acceptable level of safety has been attained.

C.I.8.2 *Offsite Power System*

C.I.8.2.1 Description

The offsite power system is the preferred source of power for the reactor protection system and engineered safety features during abnormal and accident conditions. It includes two or more physically independent circuits from the transmission network. It encompasses the grid, transmission lines (overhead or underground), transmission line towers, transformers, switchyard components and control systems, switchyard battery systems, the main generator, and so forth.

The FSAR should provide information concerning offsite power lines coming from the transmission network to the plant swithcyard. In particular, the circuits from the transmission network that are designated as two offsite power circuits and are relied upon for accident mitigation should be identified and described in sufficient detail to demonstrate conformance with General Design Criteria (GDCs) 5, 17, and 18, as set forth in Appendix A to Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50). In addition, the applicant should describe the extent to which the electrical system design conforms with the recommendations of industry standards.

The discussion should include the independence between these two offsite power sources to ensure that both electrical and physical separation exists, in order to minimize the chance of simultaneous failure. As the switchyard may be common to both offsite circuits, a failure mode and effects analysis of the switchyard components should be performed to assess the possibility of simultaneous failure of both circuits as a result of single events, such as a breaker not operating during fault conditions, a spurious relay trip, a loss of a control circuit power supply, or a fault in a switchyard bus or transformer. The capacity and electrical characteristics of transformers, breakers, buses, transmission lines, and the preferred power source for each path should also be provided to demonstrate that there is adequate capability to supply the maximum connected load during all plant conditions.

This section should also discuss the equipment that must be considered in the specification of offsite power supplies. Describe how testing is performed on the offsite power system components to demonstrate compliance with the design requirements and applicable regulations. Identify the potential effects that must be considered during testing, and the margins that are being applied and how the design incorporates these requirements for offsite power supplies. This should include, but not limited to, high-voltage transmission networks, medium-voltage distribution networks, switchyard equipment (bus work, transformers, circuit breakers, disconnect switches, surge protective devices, control, communication, grounding, and lightning systems), switching capacitors, and offsite power supplies.

The discussion should also provide information on location of rights-of-ways, transmission towers, voltage level, and length of each transmission line from the site to the first major substation that connects the line to the grid. All unusual features of these transmission lines should be described. Such features might include (but are not limited to) crossovers or proximity of other lines (to ensure that no single event such as a tower falling or a line breaking can simultaneously affect both circuits), rugged terrain, vibration or galloping conductor problems, icing or other heavy loading conditions, and high thunderstorm occurrence rate in the geographical area.

Describe and provide layout drawings of the circuits that connect the onsite distribution system to the preferred power supply. This should include transmission lines, switchyard arrangement (breakers and bus arrangements), switchyard control systems and power supplies, location of switchgear (in-plant), interconnections between switchgear, cable routing, main generator disconnect and its control system and power supply, and generator breakers and load break switch. If generator breakers are used as a means of providing immediate access from the offsite power system to the onsite ac distribution system by isolating the unit generator from the main step-up and unit auxiliary transformers and allowing back feeding of power through these circuits to the onsite ac distribution system. The FSAR should include information regarding how the applicant has followed the guidance in Appendix A to Standard Review Plan (SRP) Section 8.2, "Guidelines for Generator Circuit Breakers/Load Break Switches."

Compliance with GDC 5 requires that structures, systems, and components important to safety shall not be shared among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units. Toward that end, this section should describe how the design satisfies the requirements of GDC 5.

In addition, the FSAR should discuss the stability of the local area grid network. This should identify the equipment that must be considered for review and approval by the appropriate grid reliability planning and coordination organization(s). The FSAR should also discuss the maximum and minimum switchyard voltage that must be maintained by the transmission system provider/operator (TSP/TSO) without any reactive power support from the nuclear power plant. It should also describe the formal agreement or protocol between the nuclear power plant and the TSP/TSO of the preferred offsite power capable of supporting plant startup, and to shut down the plant under normal and emergency conditions. In addition, the FSAR should describe the capability of the TSP to analyze contingencies on the grid involving the largest generation unit outage, critical transmission line outage, and other contingencies under varying power flows in response to market conditions and system demands.

This section should also include a description of the analysis tool used by the TSO to determine, in real time, the impact of the loss or unavailability of various transmission system elements on the condition of the transmission system. In addition, this section should describe the protocols in place for the nuclear power plant to remain cognizant of grid vulnerabilities, in order to make informed decisions regarding maintenance activities that are critical to the plant's electrical system (Maintenance Rule, 10 CFR 50.65).

C.I.8.2.2 Analysis

Provide an analyses to demonstrate compliance with GDC 17 and 18, and to indicate the extent to which the recommendations of RG 1.32 are followed.

Provide an analysis of the stability of the utility grid. This analysis should include the worst case disturbances for which the grid has been analyzed and considered to remain stable. Describe how the stability of the grid is continuously studied as the loads grow and additional transmission lines and generators are added. Provide the assumptions and conclusions that demonstrate that the acceptance criteria required for the continued safe operation of the nuclear unit and the stability of the grid have been addressed. Identify the approving grid organization for the reliability studies, and identify any potential limits that may be imposed on operation of the nuclear unit. Provide a discussion of grid availability, including the frequency, duration, and causes of outages over the past 20 years for both the transmission system accepting the unit's output and the transmission system providing the preferred power for the unit's loads.

Provide the results of steady-state and transient stability analyses to demonstrate compliance with the final paragraph of GDC 17. The results of the grid stability analysis must show that loss of the largest single supply to the grid does not result in the complete loss of preferred power. The analysis should also consider the loss, as a result of a single event, of the largest capacity being supplied to the grid, removal of the largest load from the grid, or loss of the most critical transmission line. In determining the most critical transmission line, consider lines that use a common tower to be a single line. This could be the total output of the station, the largest station on the grid, or possibly several large stations if these use a common transmission tower, transformer, or breaker in a remote switchyard or substation.

C.I.8.3 Onsite Power Systems

C.I.8.3.1 <u>AC Power Systems</u>

C.I.8.3.1.1 *Description*

The onsite alternating current (ac) power system includes those standby power sources, distribution systems, and auxiliary supporting systems provided to supply power to safety-related equipment or equipment important to safety for all normal operating and accident conditions. Diesel generator sets have been widely used as a standby power source for the onsite ac power systems. Describe the onsite ac power systems, emphasizing those portions of the systems that are safety-related. Those portions that are not related to safety need only be described in sufficient detail to permit an understanding of their interactions with the safety-related portions.

The descriptive information should include functional logic diagrams, electrical single line diagrams, tables, physical arrangement drawings, and electrical schematics, describing the design of the electrical distribution systems, including grounding and lightning protection plan drawings. All functional requirements of the onsite power system (including equipment capacities and the operational environment of the onsite power system) should be described. This section should also describe how the design of the onsite power system satisfies the requirements of GDCs 2, 4, 5, 17, 18, and 50, to ensure the system will perform its intended function during all plant operating and accident conditions. In particular, the FSAR should address the following safety system requirements of GDC 17:

(1) System Redundancy Requirements

The system description should include how the redundancy is reflected in the standby power systems with regard to both power sources and associated distribution systems. It should also show how the safety-related loads and those that are important to safety are distributed between redundant divisions, and how the instrumentation systems and control devices for the Class 1E loads and power systems are supplied from the related redundant distribution systems. This should also include the ac power system configuration, including the power supplies, power supply feeders, switchgear arrangement, busing arrangements, loads supplied from each bus, safety-related equipment identification, and power connections to the instrumentation and control devices of the power systems. The information provided should demonstrate that the required redundancy of safety-related components and systems is provided, such that the system's safety function can be accomplished assuming a single failure.

(2) Conformance with the Single Failure Criterion

The onsite power system must be capable of performing its safety function assuming a single failure. In establishing the adequacy of the onsite power system to meet the single failure criterion, the FSAR should describe both electrical and physical separation of redundant power sources and associated distribution systems. This should include manual interconnection between redundant buses, buses and loads, buses and power supplies; interconnections between safety- and non-safety-related buses; physical arrangement of redundant switchgear and power supplies; and criteria and bases governing the installation of electrical cables for redundant power systems. If interconnections between redundant load centers are provided, the design must demonstrate that no single failure in the interconnections will cause paralleling of the redundant standby power supplies. IEEE Std 603, as endorsed by Regulatory Guide 1.153, provides criteria to evaluate all aspects of the electrical portions of the safety-related systems and onsite power system, including basic criteria for addressing single failures. The FSAR should also describe how the design of the onsite ac power system satisfies these criteria with respect to single failure.

(3) System Independence

The FSAR should describe how independence is established between redundant portions of the onsite power system, and between the onsite and offsite power systems. Two aspects of independence should be addressed in each case:

- physical independence
- electrical independence

In ascertaining the independence of the onsite power system with respect to the offsite power system, the FSAR should describe the electrical ties between these two systems, and should provide the physical arrangement of the interface equipment. It should also demonstrate that no single failure will prevent separation of the redundant portions of the onsite power systems from the offsite power systems. Following a loss of offsite power, the safety buses are solely fed from the standby power systems. Under this situation, describe the design of the feeder-isolation breaker in each offsite power circuit that must preclude the automatic connection of preferred power to the respective safety buses upon the loss of standby power.

If means are provided to interconnect redundant load centers through bus tie breakers, describe how the independence of the redundant portions of the system is established given a single failure.

In ensuring that the interconnections between non-Class 1E loads and Class 1E buses will not result in degradation of the Class 1E system, describe the design of the isolation device through which standby power is supplied to the non-Class 1E load, including control circuits and connections to the Class 1E bus.

To ensure physical separation between the redundant equipment, including cables and raceways, describe how the recommendations of Regulatory Guide 1.75 are followed.

Describe the acceptance criteria required for the cable and raceway design that will be incorporated into the as-built plant. This description should include (among others) criteria for cable derating; raceway; cable fill; cable routing in containment, penetration areas, cable spreading rooms, control rooms, and other congested areas; sharing of raceways with non-safety-related cables or cables of the same or other system(s); prohibiting cable splices in raceways; spacing of power and control wiring and components associated with safety-related electric systems in control boards, panels, and relay racks; and fire barriers and separation between redundant raceways.

Describe the means of identifying the onsite power system components, including cables, raceways, and terminal equipment. Provide information on the identifying scheme used to distinguish between redundant Class 1E systems, associated circuits assigned to redundant Class 1E divisions, non-Class 1E systems and their associated cables, raceways without the need to consult reference material.

(4) System Capacity and Capability

The FSAR should provide design information and analyses demonstrating the suitability of the diesel generators as standby power sources to ensure that diesel generators have sufficient capacity, capability, and reliability to perform their intended function. This should include characteristics of each load (such as motor horsepower, volt-amp rating, in-rush current, starting volt-amps, and torque) and the length of time each load is required, the combined load demand connected to each diesel generator during the "worst" operating condition, the basis for the power required for each safety load under expected flow and pressure (e.g., motor nameplate rating, pump run out condition), automatic and manual loading and unloading of each diesel generator, voltage and frequency recovery characteristics of the diesel generators, continuous and short-term ratings for the diesel generators, acceptance criteria with regard to the number of successful diesel generator tests and allowable failures to demonstrate acceptability, and starting and load shedding circuits. Where the proposed design provides for the connection of non-safety loads to the diesel generators, describe how the diesel generators are sized to accommodate the added non-Class 1E loads. An acceptable design would ensure that the total connected loads do not, at any time, exceed the continuous rating of the diesel generators. Also, discuss the degradation of reliability that may result from implementing such design provisions.

Additionally, the FSAR should describe the following design aspects of the onsite emergency electric power sources (e.g., diesel generators):

- starting initiating circuits
- starting mechanism and system
- tripping devices
- interlocks
- permissives
- load shedding circuits
- testability
- fuel oil storage and transfer system, including capacity
- cooling and heating systems
- instrumentation and control systems, including status alarms and indications, with assigned power supply
- prototype qualification program

Any features or components not previously used in similar applications in nuclear generating stations should be identified. Provide single-line diagrams of the onsite ac distribution systems, including identification of all safety loads. The physical arrangement of the components of the system should be described in sufficient detail to permit independent verification that single events and accidents will not disable redundant features. Sufficient plant layout drawings should be provided to permit evaluation of the physical separation and isolation of redundant portions of the system. The FSAR should also provide a table that illustrates the automatic and manual loading and unloading of each standby power supply. Include the time (sequence) of each event, size of load, inrush current or starting kVA, identification of redundant equipment, and length of time each load is required.

In addition, describe the bases and provide the design criteria that establish the following considerations:

- motor size
- minimum motor accelerating voltage
- motor starting torque
- minimum motor torque margin over pump torque through accelerating period
- motor insulation
- temperature monitoring devices provided in large horsepower motors
- interrupting capacity of switchgear, load centers, control centers, and distribution panels
- electric circuit protection
- grounding requirements

Describe how the onsite power system satisfies the requirements of GDC 18 and Regulatory Guides 1.9 and 1.118. Also describe how the design has the built-in capability to permit integral testing of onsite power systems on a periodic basis when the reactor is in operation. This should include (1) the operability and functional performance of the system components, such as onsite power sources, relays, switches, and buses, and (2) the operability of the systems as a whole and, under conditions as close to design as practical, the full operation sequence that brings the systems into operation, including operation of applicable portions of the protection system, and the transfer of power among the nuclear power unit, the offsite power system, and the onsite power system. Basic criteria relevant to surveillance and testability of safety-related aspects of the ac power systems are also described in IEEE Std 603 as endorsed by Regulatory Guide 1.153. Describe how the design of the onsite power system satisfies these criteria.

Regulatory Guide 1.155 provides guidance for setting minimum reliability goals for onsite ac power sources, and recommends that reliable operation of onsite ac power sources should be ensured by a reliability program designed to maintain and monitor the reliability level of each power source over time for assurance that the target reliability levels are being achieved. Apply these recommendations for both emergency and standby power supplies, and describe your reliability program for onsite ac power sources that will be implemented to ensure that the target reliability goals chosen for diesel generators are adequately maintained. Also, describe how the effectiveness of maintenance activities under the program is monitored in accordance with Regulatory Guide 1.160.

C.I.8.3.1.2 ***Analysis***

Provide analyses to demonstrate compliance with the Commission's general design criteria, and indicate the extent to which the recommendations of regulatory guides and other applicable criteria are followed. Especially important are the analyses to demonstrate compliance with GDCs 17 and 18, and to indicate the extent to which the recommendations of Regulatory Guides 1.6, 1.9, and 1.32 are followed. The discussion should identify all aspects of the onsite power system that do not conform to Regulatory Guides 1.6, 1.9, and 1.32, and should explain why such deviations are not in conflict with applicable GDCs. Identify the reliability and availability goals for the standby diesel generators.

Provide analyses to demonstrate compliance with (1) GDC 2 to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, or seiche without loss of capability to perform intended safety functions; (2) GDC 4 to protect against dynamic effects that may result from equipment failures, including missiles; and (3) GDC 5 if structures, systems, and components important to safety are shared among nuclear power units.

C.I.8.3.1.3 ***Electrical Power System Calculations, and Distribution System Studies for AC Systems***

This section of the FSAR should include the following electrical power system calculations and distribution system studies:

(1) Load Flow/Voltage Regulation Studies and Under/Over-Voltage Protection

Provide the assumptions and conclusions that demonstrate the acceptance criteria for offsite voltage swings, onsite load changes, diesel generator loading, and inverter sizing. Identify the equipment that must be considered for voltage regulation analysis, how testing is performed to demonstrate compliance, the effects that must be considered, and the margins that are applied

(2) Short Circuit Studies

Provide the assumptions and conclusions that demonstrate the acceptance criteria for medium-voltage (1000V–15000V) switchgear, 480/600 V switchgear, motor control centers, 120 Vac power panels, and electrical penetration assemblies. Identify the equipment that must be considered for overload and fault analyses, how testing is performed to demonstrate compliance, the effects that must be considered, and the margins that are applied

(3) Equipment Sizing Studies

Provide the assumptions and conclusions that demonstrate the acceptance criteria for sizing main transformers, auxiliary transformers, voltage regulators, fused load disconnects, diesel generators, medium voltage switchgear, bus and breaker sizing, unit substation transformers, 480 V switchgear bus and breakers, motor control centers and starters, control power transformer selection, 480/120 V power panels, 120 V power panels, electrical penetration assemblies, isolated and non-segregated phase bus duct, medium voltage power cables and low voltage power cables. Describe how testing is performed to demonstrate compliance, the effects that must be considered, and the margins that are applied.

(4) Equipment Protection and Coordination Studies

Identify the equipment that must be considered for equipment protection, how testing is performed to demonstrate compliance, the effects that must be considered, and the margins that are applied.

Provide the assumptions and conclusions that demonstrate the acceptance criteria for current transformers, voltage (potential) transformers; and overcurrent and fault protection using medium-voltage incoming breakers, medium-voltage tie breakers, diesel generator output breakers, medium-voltage motor feeder breaker, load center transformer primary breakers, 480/600 V incoming breakers, 480/600 V motor feeder breakers, 480/600 V motor control center (MCC) feeder breakers, MCC motor thermal overload relays, motor-operated valve thermal overload relays, medium-voltage ac power fuses, low-voltage ac power fuses, low-voltage dc power fuses, acvcontrol fuses, and dc control fuses; degraded and loss-of-voltage protection; and time delay functions. Also, discuss selectivity and coordination with upstream and downstream protective devices and other special protective devices used with large motors, generators, and transformers, as well as differences between electro-mechanical, solid-state, and numeric (microprocessor-based) relays.

(5) Insulation Coordination (Surge and Lightning Protection)

Provide analyses and any underlying assumptions used to demonstrate the acceptance criteria for the switchyard, main and auxiliary transformers, medium-voltage incoming breakers, medium-voltage switchgear, and the load center transformer. Identify the equipment that must be considered for protection of electrical insulation and coordination (surge and lightning).

(6) Power Quality Limits

Identify the equipment that must be considered for the effects of poor power quality. This includes those items that are susceptible to poor quality, and those that contribute to the problem.

Provide analyses and any underlying assumptions used to demonstrate the acceptance criteria for the digital control and protection systems, including protective devices for motors and generators. Provide the assumptions and conclusions that demonstrate that the acceptance criteria for any variable speed drives have been addressed.

(7) Monitoring and Testing

Identify the existing equipment capabilities (including redundancy and diversity or sizing margins) to permit online monitoring and testing, and specify the monitoring and testing that can only be performed during plant shutdown. This should be addressed for the safety-related onsite power systems, sequencers, inverters, and uninterruptible power supplies that are incorporated into the design.

(8) Grounding

Provide a detailed description of the grounding system, including the components associated with the various grounding subsystems (e.g., station grounding, system grounding, equipment safety grounding, any special grounding for sensitive instrumentation, and computer or low-signal control systems).

Also, identify the industry-recognized consensus standards used in designing the grounding subsystems, as well as the bases for the related acceptance criteria.

Provide analyses and any underlying assumptions used to demonstrate that the acceptance criteria for the grounding subsystems will be successfully incorporated into the as-built plant.

Additionally, Identify the analytical software (and its version), and provide an electronic copy of the model of the electrical distribution system (a single line diagram with component data) that formed the basis for the studies for items 1, 2, 3, 4, 5 and 6 above.

C.I.8.3.2 DC Power Systems

C.I.8.3.2.1 *Description*

The dc power systems include those power sources and their distribution systems that supply motive or control power to safety-related equipment. This section of the FSAR should provide a detailed description of the dc power systems, clearly delineating its safety-related portions. The non-safety-related portion need only be described in sufficient detail to permit an understanding of its interaction with the safety-related portions. The safety loads should be clearly identified, and the length of time they would be operable in the event of a loss of all ac power should be stated.

The descriptive information should include functional logic diagrams, electrical single line diagrams, tables, physical arrangement drawings, and electrical schematics describing the design of the dc distribution systems. This section should also describe how the design of the dc power system satisfies the requirements of GDCs 2, 4, 5, 17, 18, and 50 to ensure that the system will perform its intended function during all plant operating and accident conditions. In particular, the FSAR should address the following safety system criteria of GDC 17:

(1) System Redundancy Requirements

The system description should include how redundancy is reflected in the dc power systems with regard to both power sources and their associated distribution systems. This should include the dc power configuration, including the batteries, battery chargers, power supply feeders, panel arrangements, loads supplied from each battery, safety-related equipment identification, and power connections to the inverters. The information provided should demonstrate that the required redundancy of safety-related components and systems is provided such that the system's safety function can be accomplished assuming a single failure.

(2) Conformance with the Single Failure Criterion

The dc power system must be capable of performing its safety function, assuming a single failure. Describe both electrical and physical separation of redundant batteries, battery chargers, and associated distribution systems including their connected loads to demonstrate the independence between the redundant portions of the systems. IEEE Std 603, as endorsed by Regulatory Guide 1.153, provides criteria to evaluate all aspects of the electrical portions of the safety-related systems and onsite power system, including basic criteria for addressing single failures. Describe how the design of dc power systems satisfies these criteria with respect single failure.

(3) System Independence

In ascertaining the independence of the redundant dc power system, the FSAR should describe the electrical ties (if any) between the redundant systems, and provide the physical arrangement of the equipment. It should also demonstrate that no single failure will prevent the separation of the redundant portions of the dc power system and its distribution systems. Demonstrate that no single failure in the interconnections or inadvertent closure of interconnecting devices will compromise division independence in a manner that will cause paralleling of the dc power supplies.

To ensure physical separation between the redundant equipment, including cables and raceways, describe how the recommendations of Regulatory Guide 1.75 are followed.

Describe the acceptance criteria required for the cable and raceway design that will be incorporated into the as-built plant. This description should include (among others) criteria for cable derating; raceway filling; cable routing in containment, penetration areas, cable spreading rooms, control rooms, and other congested areas; sharing of raceways with non-safety-related cables or cables of the same or other system(s); prohibiting cable splices in the raceways; spacing of power and control wiring and components associated with safety-related electric systems in control boards, panels, and relay racks; and fire barriers and separation between redundant raceways.

Describe the proposed means for physically identifying the onsite power system components, including cables, raceways, and terminal equipment. Provide the identifying scheme used to distinguish between redundant Class 1E systems; associated circuits assigned to redundant Class 1E divisions; and non-Class 1E systems and their associated cables and raceways, without the need to consult reference material.

(4) System Capacity and Capability

Provide design information about the suitability of batteries and battery chargers as dc power supplies and inverters that provide instrumentation and control power. Demonstrate that they have sufficient capacity and capability to perform their intended function. This should include characteristics of each load (such as motor horsepower, volt-amp rating, in-rush current, starting volt-amps, and torque), the length of time each load is required, and the basis used to establish the power required for each safety related load to verify the calculations establishing the combined load demand to be connected to each dc supply during the "worst' operating conditions. Also, include the voltage recovering characteristics of batteries and battery chargers, as well as the continuous and short-term rating of batteries and battery chargers. Include performance characteristic curves that illustrate the response of the supplies to the most severe loading conditions at the plant. The performance characteristic curves should include voltage profile curves, discharge rate curves, and temperature effect curves. In addition, where the proposed design provides for connection of non-safety loads to the dc system, the batteries and the battery chargers should be sized to accommodate the added non-Class 1E loads. Also, discuss the degradation of reliability that may result from implementing such design provisions.

Also, describe how the dc power system satisfies the requirements of GDC 18 and the recommendations of Regulatory Guide 1.118. Describe how the operability and functional performance of the components of the dc power systems are tested.

C.I.8.3.2.2 ***Analysis***

Provide analyses to demonstrate compliance with the Commission's general design criteria, and indicate the extent to which the recommendations of regulatory guides and other applicable criteria are followed. Especially important are the analyses to demonstrate compliance with GDCs 17 and 18, and indicate the extent to which the recommendations of Regulatory Guides 1.6, and 1.32 are followed. The discussion should identify all aspects of the dc power system that do not conform to Regulatory Guides 1.6, and 1.32, and should explain why such deviations are not in conflict with applicable GDCs.

Provide analyses to demonstrate how the dc power system satisfies the requirements of (1) GDC 2 to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, or seiche without loss of capability to perform intended safety functions; (2) GDC 4 to protect against dynamic effects that may result from equipment failures, including missiles; and (3) GDC 5 if structures, systems, and components important to safety are shared among nuclear power units.

C.I.8.3.2.3 ***Electrical Power System Calculations, and Distribution System Studies for DC Systems***

This section of the FSAR should include the following electrical power system calculations and distribution system studies:

(1) Load Flow and Under/Over-Voltage Protection

Identify the allowable voltage ranges for equipment connected to the dc systems. Describe how testing is performed on the dc system and components to demonstrate compliance with the design requirements and applicable regulations. Identify the potential effects that must be considered during testing, and the margins that are being applied. Also, provide the assumptions and conclusions that demonstrate the acceptance criteria for onsite load changes, battery charger and inverter sizing and battery discharge voltage profiles.

(2) Short Circuit Studies

Identify the equipment that must be considered for overload and fault analyses. Describe how testing is performed on the dc system and components to demonstrate compliance with the design requirements and applicable regulations. Identify the potential effects that must be considered during testing, and the margins that are being applied, how testing is performed to demonstrate compliance, the effects that must be considered, and the margins that are applied. Also, provide the assumptions and conclusions that demonstrate the acceptance criteria for (125/250 V) dc switchgear and power panels and electrical penetration assemblies.

(3) Equipment Sizing Studies

Identify the equipment that must be considered for equipment sizing. Describe how testing is performed on the dc system and components to demonstrate compliance with the design requirements and applicable regulations. Identify the potential effects that must be considered during testing, and the margins that are being applied. Also, provide the assumptions and conclusions that demonstrate the acceptance criteria for stationary and special purpose batteries, dc switchgear bus and breakers, battery chargers, inverters and uninterruptible power supplies, (125/250 V) dc power panels, electrical penetration assemblies and low-voltage power cables. Identify the design, temperature, and aging margins provided in sizing the batteries.

(4) Equipment Protection and Coordination Studies

Identify the equipment that must be considered for equipment protection. Describe how testing is performed on the dc system and components to demonstrate compliance with the design requirements and applicable regulations. Identify the potential effects that must be considered during testing, and the margins that are being applied. Also, provide the assumptions and conclusions that demonstrate the acceptance criteria for overcurrent and fault protection using dc rated circuit breakers, dc power fuses, and dc control fuses; degraded and loss-of-voltage protection; and time delay functions. This area should also discuss selectivity and coordination with upstream and downstream protective devices.

(5) Power Quality Limits

Identify the equipment that must be considered for the effects of poor power quality. This includes identifying those components that are susceptible to poor dc voltage quality, are sensitive to ripple voltage on the steady-state dc voltage, or contribute to the problem.

Provide analyses and any underlying assumptions used to demonstrate the acceptance criteria for the permissible conducted and radiated EMI/RFI, and the limits for the harmonic content of the power to the inverters and battery chargers.

(6) Monitoring and Testing

Identify the existing equipment capabilities (including redundancy and diversity or sizing margins) to permit online monitoring and testing, as well as the monitoring and testing that can only be performed during plant shutdown. This should be addressed for the safety-related (125 V) batteries, (250 V) batteries, battery chargers, inverters, and uninterruptible power supplies that are incorporated into the design.

Describe any online monitoring system that may be used to monitor the voltage, specific gravity electrolyte temperature, and electrolyte level on a continuing basis.

Describe any special features of the design that would permit online replacement of an individual cell, a group of cells, or an entire battery.

(7) Grounding

This section should include the same information described for grounding in Section C.I.8.3.1.2 of this regulatory guide if the dc system is a grounded system, if not, describe the ground detection system and equipment grounding.

Additionally, Identify the analytical software (and its version), and provide an electronic copy of the model of the electrical distribution system (a single line diagram with component data) that formed the basis for the studies for items 1, 2, 3, 4, and 5 above.

C.I.8.4 *Station Blackout (SBO)*

C.I.8.4.1 Description

10 CFR 50.63, "Loss of All Alternating Current Power," requires that each light-water-cooled nuclear power plant must be designed to be able to withstand or cope with, and recover from a station blackout for a specified duration. This section of the FSAR should describe how the design demonstrates compliance with 10 CFR 50.63, and should indicate the extent to which the recommendations of Regulatory Guides 1.155 are followed. Provide the specified duration of time that a plant should be able to cope with an SBO. Describe how the use of redundancy and reliability of emergency onsite power sources are factors in determining an appropriate SBO duration that the plant should be capable of withstanding or coping with, and recovering from. Provide the target reliability levels chosen for emergency onsite ac power sources and a reliability program that provides reasonable assurance that reliability targets will be achieved and maintained. An acceptable reliability program should be based on meeting the relevant positions of Regulatory guide 1.155. Describe how your design satisfies the recommendations of this guide in that regard. In addition, describe the procedures and training provided for the plant operators for the SBO event for the specified duration and recovery therefrom.

A preferred means of complying with the requirements of 10 CFR 50.63 would require an installation of an AAC power source of diverse design with sufficient capacity, capability, and reliability that will be available on a timely basis for powering at least one complete set of normal safe shutdown loads (non-design-basis accident). Describe the AAC power source provided for SBO mitigation. Include information regarding the adequacy, availability, capacity, and reliability of the AAC power source, and demonstrate the plant's ability to withstand an SBO event until the source can be brought online to support safe shutdown (non-design-basis accident). Describe how the design of the AAC power source meet the recommendations of Regulatory Guide 1.155 and Nuclear Management and Resources Council (NUMARC) promulgated as NUMARC-8700, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," dated November 1987. AAC power sources may be nearby or onsite gas turbine generators, portable or other available compatible diesel generators, hydro generators, or black-start-capable fossil fuel power plants. In general, equipment required to cope with an SBO event should be available onsite. Consideration should be given to the availability and accessibility of offsite equipment in the time required, including consideration of weather conditions that are likely to prevail during a loss of offsite power.

The AAC power source should be independent from the offsite power and onsite power systems and sources. Describe the physical arrangement of circuits and incoming source breakers [to the affected Class 1E bus(es)], separation and isolation provisions (control and main power), permissive and interlock schemes proposed for source breakers, source initiation/transfer logic, Class 1E load shedding and sequencing schemes that could affect the ability of the AAC source to power safe shutdown loads, source lockout schemes, and bus lockout schemes in arriving at the determination that the independence of the AAC power source is maintained.

The AAC power source should not be normally directly connected to the preferred power system or the blacked-out unit's onsite emergency ac power system. Demonstrate that no single-point vulnerability exists whereby a single active failure or weather-related event could simultaneously fail the AAC power source and preferred power sources or simultaneously fail the AAC and onsite sources. The power sources should have minimum potential for common failure modes.

In addition, identify local power sources and transmission paths that could be made available to resupply power to the plant following loss of a grid or SBO.

C.I.8.4.2 <u>Analysis</u>

Provide an analysis for determining the minimum time for which a plant can withstand or cope with a station blackout (SBO duration), and the plant's capability to maintain adequate core cooling and appropriate containment integrity for the SBO duration and subsequent recovery from the event. Especially important are the analyses to demonstrate compliance with 10 CFR 50.63 and to indicate the extent to which the recommendations of Regulatory Guides 1.155 are followed.

In addition, provide an analysis to demonstrate that no single-point vulnerability exists whereby a single active failure or weather-related event could simultaneously fail the AAC power source, the onsite power sources and the offsite power sources.

For passive design plants, identify the minimum duration for operating only on safety-related batteries, and identify the paths available to recharge the batteries.