

## **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 applicant should provide information in Chapter 8 of the final safety analysis report (FSAR) on the functional adequacy of the offsite power systems and safety-related onsite electric power systems (as applicable to passive and nonpassive designs) 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). For passive designs that are exempt from providing the two offsite power sources required by General Design Criterion (GDC) 17, "Electric Power Systems," in Appendix A, "General Design Criteria for Nuclear Power Plants," in Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50), the applicant should provide at least one offsite power circuit from the transmission network to power the safety-related systems during normal, abnormal, and accident conditions.

### **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 alternate alternating current (AAC) power source (for nonpassive designs) provided to mitigate station blackout (SBO) and its 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 (alternating current (ac) or direct current (dc)) required by each safety load.

In addition, the applicant should present and discuss the design bases, criteria, regulatory guides, standards, and other documents to be used 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 1.29, "Seismic Design Classification"
  - 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 1.40, "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
  - Branch Technical Position 8-1, “Requirements on Motor-Operated Valves in the ECCS Accumulator Lines”
  - Branch Technical Position 8-2, “Use of Diesel Generator Sets for Peaking”
  - Branch Technical Position 8-3, “Stability of Offsite Power Systems”
  - Branch Technical Position 8-4, “Application of Single Failure Criterion to Manually Controlled Electrically Operated Valves”
  - Branch Technical Position 8-5, “Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems.”
  - Branch Technical Position 8-6, “Adequacy of Station Electric Distribution System Voltages”
  - Branch Technical Position 8-7, “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”
  - Generic Letter 2007-01, “Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients”
- 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, “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 1E 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, "Standard Criteria for 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 the applicants use alternative approaches, they should justify the alternative approach by demonstrating attainment of an acceptable level of safety.

### **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 normal, 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 switchyard. In particular, the applicant should identify the circuits from the transmission network that are designated as two offsite power circuits and are relied on for accident mitigation and should describe them in sufficient detail to demonstrate conformance with GDC 2, "Design Bases for Protection Against Natural Phenomena"; GDC 4, "Environmental and Dynamic Effects Design Bases"; GDC 5, "Sharing of Structures, Systems, and Components"; GDC 17; and GDC 18, "Inspection and Testing of Electric Power Systems," as given in Appendix A to 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.

For the passive designs that are exempted from providing the two offsite power sources required by GDC 17, the applicant should provide information on the single designated offsite power circuit

provided from the transmission network with sufficient capacity and capability to power safety systems under normal, abnormal, and accident conditions. This power source should be the preferred source of power for passive plants.

For evolutionary light-water reactor designs, the applicant should provide information on the design that includes at least one offsite circuit to each redundant safety division that is supplied directly from an offsite power source with no intervening nonsafety buses, thereby permitting the offsite source to supply power to safety buses if the nonsafety buses fail. The applicant should also provide information on the design that includes an alternate power source to nonsafety loads, unless existing design margins are sufficient to demonstrate that transients for loss of nonsafety power events are no more severe than those associated with the turbine-trip-only events in the current plants.

For nonpassive designs, 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, the applicant should provide a failure mode and effects analysis (FMEA) of the switchyard components 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. For passive designs, the FMEA should ensure that a single event such as a breaker not operating during fault condition, a loss of control circuit power supply or a fault in a switch bus does not cause failure of the single designated offsite line. The applicant should also provide the capacity and electrical characteristics of transformers, breakers, buses, transmission lines, and the preferred power source for each path 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. It should describe how testing is performed on the offsite power system components to demonstrate compliance with the design requirements and applicable regulations. The applicant should identify the potential effects that must be considered during testing, the margins being applied, and how the design incorporates these requirements for offsite power supplies, including, 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 voltage control equipment between the switchyard and the plant.

For nonpassive designs, the discussion should also provide information on location of rights-of-way, 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. The applicant should describe all unusual features of these transmission lines. 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. For passive designs, the applicant should provide similar information, as applicable, for the single designated offsite power circuit provided from the transmission network.

The applicant should describe and provide layout drawings of the circuit(s) connecting the onsite distribution system to the preferred power supply. These 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 these circuits

are routed underground, cables from independent power sources or different safety divisions could be affected by the same environments. Underground power cables connecting offsite power to safety buses or power and control cables to equipment with accident mitigation functions that are susceptible to wetted conditions or submergence should be described. For nonpassive designs, 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 backfeeding of power through these circuits to the onsite ac distribution system, the applicant should include information regarding how the applicant has followed the guidance in Appendix A to Standard Review Plan Section 8.2.

In addition, the applicant should discuss the stability of the grid. This discussion should identify the equipment that must be considered for review and approval by the appropriate grid reliability planning and coordination organization(s). The applicant 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 and actions that will be taken by the plant operator when these voltages can not be maintained by the TSP/TSO. It should also describe the formal agreement or protocol between the nuclear power plant and the TSP/TSO regarding the preferred offsite system capability to support plant startup, and shut down under normal and emergency conditions. In addition, the applicant 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 describe 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 (10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," also known as the Maintenance Rule).

#### **C.I.8.2.2 Analysis**

The applicant should provide an analysis to demonstrate compliance with GDCs 17 and 18 and to indicate the extent to which it has followed the recommendations of Regulatory Guide 1.32.

The applicant should provide an analysis of the stability of the grid. This analysis should include the worst-case disturbances for which the grid has been analyzed and considered to remain stable. The applicant should describe how the stability of the grid is continuously studied as the loads grow and more transmission lines and generators are added and provide the assumptions and conclusions that demonstrate that the applicant has addressed the acceptance criteria required for the continued safe operation of the nuclear unit and the stability of the grid. The applicant should identify the approving grid organization for the reliability studies and any potential limits that may be imposed on operation of the nuclear unit. This section should also discuss 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.

The applicant should 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 generation 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, the applicant should 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. For passive designs, the analysis should show that the single designated offsite circuit from the transmission network is not degraded as a result of the above contingencies. In addition, the grid analyses should verify that the grid remains stable for a minimum of 3 seconds following a turbine trip to support assumptions made in safety analyses for pressurized-water reactor passive designs.

### ***C.I.8.3 Onsite Power Systems (for nonpassive designs except as noted)***

#### **C.I.8.3.1 AC Power Systems**

##### ***C.I.8.3.1.1 Description***

The onsite 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 are widely used as a standby power source for the onsite ac power systems. The applicant should describe the onsite ac power systems, emphasizing those portions of the systems that are safety-related. Those portions that are not related to safety should be described only in sufficient detail to permit an understanding of their interactions with the safety-related portions. In passive designs, risk-important, non-safety related active systems may have a significant role in accident and consequence mitigation by providing defense-in-depth functions to supplement the capability of the safety-related passive systems. The applicants should describe the onsite ac power systems needed to support those risk-important, nonsafety-related active systems identified through the regulatory treatment of nonsafety systems process.

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. The description should include all functional requirements of the onsite power system (including equipment capacities and the operational environment of the onsite power system). 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, "Containment Design Basis," 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 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 plant has the required redundancy of safety-related components and systems, such that, assuming a single failure, the system can accomplish its safety function.

(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 applicant 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 nonsafety-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 the design provides for interconnections between redundant load centers, it 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 applicant should also describe how the design of the onsite ac power system satisfies these criteria with respect to single failure.

(3) System Independence

The applicant should describe how independence is established between redundant portions of the onsite power system and between the onsite and offsite power systems. It should address two aspects of independence in each case:

- physical independence
- electrical independence

In ascertaining the independence of the onsite power system with respect to the offsite power system, the applicant should describe the electrical ties between these two systems and 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. The applicant should 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 in this situation. For passive designs, the applicant should describe the electrical tie between the single offsite power circuit from the transmission network to the onsite distribution system that supplies power to the safety systems and the associated arrangement of the interface equipment.

To ensure independence between the offsite and the onsite power systems, this section should describe how the design of the degraded voltage relay scheme satisfies Branch Technical Position 8-6 to preserve this independence.

If the design provides a means to interconnect redundant load centers through bus tie breakers, this section should 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, this section should 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, the applicant should describe the extent to which it follows the recommendations of IEEE Std. 384 and Regulatory Guide 1.75 and justify any exceptions.

The applicant should describe the acceptance criteria required for the cable and raceway design to be incorporated into the as-built plant. This description should include 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 nonsafety-related cables or cables of the same or other system(s); prohibition of 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.

The applicant should describe the means of identifying the onsite power system components, including cables, raceways, and terminal equipment. The applicant should provide information on 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

The applicant 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 runout condition, efficiency, and power factor), 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 nonsafety loads to the diesel generators, the applicant should 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, the applicant should discuss the degradation of reliability that may result from implementing such design provisions.

Additionally, the applicant 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

The applicant should identify any features or components not previously used in similar applications in nuclear generating stations. The applicant should provide single-line diagrams of the onsite ac distribution systems, including identification of all safety loads. The description of the physical arrangement of the components of the system should be sufficiently detailed to permit independent verification that single events and accidents will not disable redundant features. The applicant should provide sufficient plant layout drawings to permit evaluation of the physical separation and isolation of redundant portions of the system. The applicant should also include a table that illustrates the automatic and manual loading in kW and kVAR and unloading of each standby power supply and includes the time (sequence) of each event, size of load, in-rush current or starting kVA, identification of redundant equipment, and length of time each load is required.

In addition, the applicant should 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 at minimum applied voltage
- 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
- forced cooling requirements

The applicant should describe how the onsite power system satisfies the requirements of GDC 18 and Regulatory Guides 1.9 and 1.118 and describe the design's 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. As endorsed by Regulatory Guide 1.153, IEEE Std 603 describes basic criteria relevant to surveillance and testability of safety-related aspects of the ac power systems. The applicant should 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 the applicant ensure dependable operation of onsite ac power sources through a reliability program designed to maintain and monitor the reliability level of each power source over time to ensure the achievement of the target reliability levels. The applicant should apply these recommendations for both emergency and standby power supplies and describe its reliability

program for onsite ac power sources to be implemented to ensure the attainment of the target reliability goals chosen for diesel generators. The applicant should also describe how it monitors the effectiveness of maintenance activities under the program in accordance with Regulatory Guide 1.160.

For all designs, the applicant should describe how it satisfies GDC 50 as the criterion relates to the design of containment electrical penetrations containing circuits of the ac power system and the extent to which it follows the guidelines of IEEE Std. 317 and Regulatory Guide 1.63 as they relate to the capability of electrical penetration assemblies in containment structures to withstand a loss-of-coolant accident without loss of mechanical integrity and external circuit protection for such penetrations to ensure that electrical penetrations will withstand all ranges of overcurrent and short-circuit current up to the maximum fault current versus time conditions that could occur given single random failures of circuit protective devices.

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

The applicant should provide analyses to demonstrate compliance with the GDCs and indicate the extent to which it has followed the recommendations of regulatory guides and other applicable criteria. Especially important are the analyses to demonstrate compliance with GDCs 17 and 18 and to indicate the extent to which it has followed the recommendations of Regulatory Guides 1.6, 1.9, and 1.32. 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. The applicant should identify the reliability and availability goals for the standby diesel generators.

The FSAR should contain 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 the nuclear power units share structures, systems, and components important to safety.

#### **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-/Overvoltage 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 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 (2000 volts (V)–15,000 V) switchgear, 480/600-V switchgear, motor control centers, 120-V ac power panels, and electrical penetration assemblies.
  - Identify the equipment that must be considered for overload and fault analyses, the testing 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 nonsegregated phase bus duct, medium-voltage power cables, and low-voltage power cables.
- Describe the testing 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, the testing 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; overcurrent and fault protection (for 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 feeder breakers, etc.); degraded and loss-of-voltage protection; and time delay functions.
- Discuss selectivity and coordination with upstream and downstream protective devices and other special protective devices used with large motors, generators, and transformers.

(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 application has addressed the acceptance criteria for any variable speed drives.

(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 be performed only during plant shutdown.
- Address these items for the safety-related onsite power systems, sequencers, inverters, and uninterruptible power supplies incorporated in 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).
- 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, the applicant should identify the analytical software (and its version) and provide an electronic copy of the model of the electrical distribution system and a single-line diagram with component data) that formed the basis for the studies for items 1 through 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 describe the dc power systems in detail and clearly delineate its safety-related portions. The nonsafety-related portion need be described only in sufficient detail to permit an understanding of its interaction with the safety-related portions. This section should clearly identify the safety loads and state the length of time they would be operable in the event of a loss of all ac power.

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 GDC 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 applicant 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 plant can accomplish its safety function in the event of a single failure.

(2) Conformance with the Single-Failure Criterion

The dc power system must be capable of performing its safety function in the event of a single failure. This section should 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. This section should describe how the design of dc power systems satisfies these criteria with respect to a single failure.

(3) System Independence

In ascertaining the independence of the redundant dc power system, the applicant should describe the electrical ties (if any) between the redundant systems and 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. This section should also show 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, the applicant should describe how it has followed the recommendations of IEEE Std. 384 and Regulatory Guide 1.75 and justify any exceptions.

The applicant should describe the acceptance criteria required for the cable and raceway design that will be incorporated into the as-built plant. This description should include 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 nonsafety-related cables or cables of the same or other system(s); prohibition of 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.

This section should describe the proposed means for physically identifying the onsite power system components, including cables, raceways, and terminal equipment. It should 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

The applicant should provide design information about the suitability of batteries and battery chargers as dc power supplies and inverters that provide instrumentation and control power and demonstrate that they have sufficient capacity and capability to perform their intended function. This information should include characteristics of each load (such as motor horsepower, volt-amp rating, in-rush current, starting volt-amperes, 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. This section should 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. It should include performance characteristic curves illustrating 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 nonsafety loads to the dc system, the discussion should cover the sizing of batteries and battery chargers to accommodate the added non-Class 1E loads. Also, this section should discuss the degradation of reliability that may result from implementing such design provisions.

The applicant should also describe how the dc power system satisfies the requirements of GDC 18 and the recommendations of Regulatory Guide 1.118 and the testing of the operability and functional performance of the components of the dc power systems.

The applicant should explain how it has satisfied GDC 50, as it relates to the design of electrical penetrations containing circuits of dc power system, and the extent to which it has followed the guidelines of IEEE Std. 317 and Regulatory Guide 1.63 related to the capability of electrical penetration assemblies in containment structures to withstand a loss-of-coolant accident without loss of mechanical integrity and external circuit protection for such penetrations to ensure that electrical penetrations will withstand all ranges of overcurrent and short-circuit current up to the maximum fault current versus time conditions that could occur given single random failures of circuit protective devices.

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

The applicant should provide analyses to demonstrate compliance with the GDCs and indicate the extent to which it has followed the recommendations of regulatory guides and other applicable criteria. Especially important are the analyses to demonstrate compliance with GDCs 17 and 18 and the discussion of the extent to which the applicant has adhered to the recommendations of Regulatory Guides 1.6 and 1.32. 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.

The applicant should also 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-/Overvoltage 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 being applied.
  - Provide the assumptions and conclusions that demonstrate the acceptance criteria for battery and battery charger sizing, and provide battery discharge voltage profiles.

- (2) Short-Circuit Studies
- Identify the equipment that must be considered for overload and fault analyses.
  - Describe the testing 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 being applied.
  - Provide the assumptions and conclusions that demonstrate the acceptance criteria for dc switchgear and power panels and electrical penetration assemblies.
- (3) Equipment Sizing Studies
- Identify the equipment that must be considered for equipment sizing.
  - Describe the testing 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 being applied.
  - 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, 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 protection.
  - Describe the testing 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 being applied.
  - 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.
  - 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 electromagnetic/radiofrequency interference and the limits for the harmonic content of the power to the inverters and battery chargers.
- (6) Monitoring and Testing
- Identify the equipment capabilities (including redundancy and diversity or sizing margins) to permit online monitoring and testing, as well as the monitoring and testing that can be performed only during plant shutdown. Address this for the safety-related



batteries, battery chargers, inverters, and uninterruptible power supplies that are incorporated into the design.

- For passive designs which utilize 72-hour batteries, describe how the battery discharge test will be monitored for the 72 hours discharge test and provide the acceptable test data/criteria to be used for this long-duration test.
- 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 it is not, the applicant should describe the ground detection system and equipment grounding.

Additionally, the applicant should 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 through 5 above.

**C.I.8.4 Station Blackout (for nonpassive designs except as noted)**

**C.I.8.4.1 Description**

According to 10 CFR 50.63, "Loss of All Alternating Current Power," each light-water-cooled nuclear power plant must be designed to be able to withstand or cope with and recover from an station blackout (SBO) 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 applicant has followed the recommendations of Regulatory Guide 1.155. This section should specify the duration of time that a plant should be able to cope with an SBO and describe how redundancy and reliability of emergency onsite power sources are factors in determining an appropriate SBO duration which the plant should be capable of withstanding or coping with and recovering from. This section should also 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. The applicant should base its reliability program on the relevant positions of Regulatory Guide 1.155 and describe in this section how its design satisfies the recommendations of this guide. In addition, for all designs, describe the procedures and training provided for the plant operators for the SBO event for the specified duration and recovery periods.

A preferred means of complying with the requirements of 10 CFR 50.63 for evolutionary designs would require the 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 (nondesign-basis accident) to bring the plant to cold shutdown. The applicant should describe the AAC power source provided for SBO mitigation. This description should 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 on line to support safe shutdown (nondesign-basis accident). It should also describe how the design of the AAC power source meets the recommendations of Regulatory Guide 1.155 and Nuclear Management and Resources Council (NUMARC) guidance promulgated as NUMARC-8700, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," issued November

1987. The 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 on site. The applicant should consider the availability and accessibility of offsite equipment in the time required and include in its consideration the weather conditions 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. This section should 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 to show how the applicant determined that the independence of the AAC power source is maintained.

Normally, the AAC power source should not be directly connected to the preferred power system or the blacked-out unit's onsite emergency ac power system. The applicant should 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.

The passive designs need to demonstrate that safety-related functions can be performed without reliance on ac power for 72 hours after the initiating event.

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

#### **C.I.8.4.2 Analysis**

The applicant should provide an analysis for determining the minimum time for which a plant can withstand or cope with an SBO (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 applicant has followed the recommendations of Regulatory Guide 1.155.

In addition, the applicant should 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 designs, the applicant should identify the minimum duration for operating only on safety-related batteries and identify the paths available to recharge the batteries.