2.13.3 Direct Current Power Supply

Design Description

The plant direct current (DC) power supply system shall consist of five non-divisional 250 VDC power supplies, two non-divisional 125 VDC power supplies, and eight 72-hour divisional Class 1E 250 VDC power supplies.

The eight 72-hour Class 1E DC power supplies provide power to 120Vac Class 1E inverters for post-accident monitoring, MCR emergency lighting and safe shutdown loads.

Each of the four divisions of Class 1E DC power is separate and independent. Divisions 1, 2, 3 and 4 each have two 72-hour batteries. The DC systems operate ungrounded (with ground detection circuitry) for increased reliability. Each division has a battery and a battery charger fed from its divisional Motor Control Center (MCC). This system is designed so that no single failure in any division prevents safe shutdown of the plant.

The Class 1E DC power supply is designed to permit periodic testing for operability and functional performance.

Nonsafety-related DC power is supplied through four non-Class 1E MCCs in the same manner as the Class 1E DC power. Each of the two load groups receives power from two of the non-Class 1E MCCs. One MCC in each group provides power to a bus through a battery charger.

Alarms annunciate in the Main Control Room to indicate loss of battery chargers and inverters. Computer inputs can then be monitored to determine the source of the problem. Annunciator and computer inputs from Class 1E equipment or circuits are treated as Class 1E and retain their divisional identification up through their Class 1E isolation device. The output circuit from this isolation device is classified as non-Class 1E. The plant design and circuit layout of the DC systems provide physical separation of the equipment, cabling, and instrumentation essential to plant safety. Each 250VDC battery is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each division of the DC distribution system is located in an area separated physically from the other divisions. All the components of Class 1E 250 VDC systems are housed in Seismic Category I structures. The battery charger output is of a current limiting design. The battery charger output voltage is protected against over voltage by a high voltage shutdown circuit. The over voltage protection feature is incorporated to protect equipment from damage caused by high voltage. When high voltage occurs, the unit disconnects the auxiliary voltage transformer, which results in charger shutdown. An initial composite test of the on-site DC power systems is called for as a prerequisite to initial fuel loading. This test verifies that each battery capacity is sufficient to satisfy a safety load demand profile under conditions of a LOCA and loss of preferred power. Battery capacity tests are conducted. These tests ensure that the battery has the capacity to meet safety load demands.

Inspections, Tests, Analyses and Acceptance Criteria

Table 2.13.3-1 provides a definition of the inspections, tests, and/or analyses, together with associated acceptance criteria, which will be undertaken for the Direct Current Power Supply.

Table 2.13.3-1

ITAAC For The Direct Current Power Supply

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1. The basic configuration of the Direct Current Power Supply is described in Subsection 2.13.3.	1. Inspections of the as-built system will be conducted.	1. The as-built Direct Current Power Supply conforms to the basic configuration described in Subsection 2.13.3.
2. Each Class 1E divisional (Divisions 1, 2, 3, and 4) battery is provided with a normal and a standby battery charger supplied AC power from a MCC in the same Class 1E division as the battery.	2. Inspections of the as-built Class 1E Direct Current Power Supply will be conducted.	2. Verify that each as-built Class 1E divisional (Divisions 1, 2, 3, and 4) battery is provided with a normal and a standby battery charger supplied AC power from a MCC in the same Class 1E division as the battery.
3. Two sets of 72-hour batteries in each division are sized to supply its design loads, at the end-of-installed-life, for a minimum of 72 hours without recharging.	3. a. Analyses for the as-built Class 1E batteries to determine battery capacities will be performed based on the design duty cycle for each battery. b. Tests of each as-built class 1E battery will be conducted by simulating loads which envelope the analyzed battery design duty cycle.	3. a. Analyses for the as-built Class 1E batteries exist and conclude that two sets of Class 1E batteries in each division have the capacity, as determined by the as-built battery rating, to supply its analyzed design loads, at the end-of-installed-life, for a minimum of 72 hours without recharging. b. The capacity of each as-built Class 1E battery equals or exceeds the analyzed battery design duty cycle capacity.

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
4. Each Class 1E normal battery charger is sized to supply its respective Class 1E division's normal steady state loads while charging its respective Class 1E battery.	4. Tests of each as-built Class 1E normal battery charger will be conducted by supplying its respective Class 1E division's normal steady state loads while charging its respective Class 1E battery.	4. Each as-built Class 1E normal battery charger can supply its respective Class 1E division's normal steady state loads while charging its respective Class 1E battery.
5. The Class 1E DC battery and battery charger circuit breakers, DC distribution panels, and their circuit breakers and fuses, are sized to supply their load requirements.	5. a. Analyses for the as-built Class 1E DC electrical distribution system to determine the capacities of the battery and battery charger circuit breakers DC distribution panels, and their circuit breakers and fuses, will be performed. b. Tests of the as-built Class 1E battery and battery charger circuit breakers, DC distribution panels, their circuit breakers and fuses, will be conducted by operating connected Class 1E loads at greater than or equal to the minimum allowable battery voltage and at less than or equal to the maximum battery charging voltage.	5. a. Analyses for the as-built Class 1E DC electrical distribution system exist and conclude that the capacities of Class 1E battery and battery charger circuit breakers, DC distribution panels, and their circuit breakers and fuses, as determined by their nameplate ratings, exceed their analyzed load requirements. b. Connected as-built Class 1E loads operate at greater than or equal to the minimum allowable battery voltage and at less than or equal to the maximum battery charging voltage.

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
6.	6.	6.
a. The Class 1E battery, battery chargers, and DC distribution panels are rated to withstand fault currents for the time required to clear the fault from its power source.	a. Analyses for the as-built Class 1E DC electrical distribution system to determine fault currents will be performed.	a. Analyses for the as-built Class 1E DC electrical distribution system exist and conclude that the capacities of as-built Class 1E battery, battery charger, DC distribution panel, and current capacities exceed their analyzed fault currents for the time required, as determined by the circuit interrupting device coordination analyses, to clear the fault from its power source.
b. Class 1E battery, battery charger and DC distribution panel circuit breakers and fuses are rated to interrupt fault currents.	b. Analyses for the as-built Class 1E DC electrical distribution system to determine fault currents will be performed.	b. Analyses for the as-built Class 1E DC electrical distribution system exist and conclude that the analyzed fault currents do not exceed the battery, battery charger and DC distribution panel, circuit breaker and fuse interrupt capacities, as determined by their nameplate ratings.
7. Each Class 1E battery is located in a Seismic Category I structure and in its respective divisional battery room.	7. Inspections of the as-built Class 1E batteries will be conducted.	7. Verify that each as-built Class 1E battery is located in a Seismic Category I structure and in its respective divisional battery room.
8. Class 1E DC distribution panels are identified according to their Class 1E division and are located in Seismic Category I structures and in their respective divisional areas.	8. Inspections of the as-built Class 1E DC distribution panels will be conducted.	8. As-built DC distribution panels are identified according to their Class 1E division and are located in Seismic Category I structures and in their respective divisional areas.

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
9. Class 1E DC distribution system cables and raceways are identified according to their Class 1E division. Class 1E divisional cables are routed in Seismic Category I structures and in their respective divisional raceways.	9. Inspections of the as-built Class 1E DC distribution system cables and raceways will be conducted.	9. Verify that as-built Class 1E DC distribution system cables and raceways are identified according to their Class 1E division. Verify that Class 1E divisional cables are routed in Seismic Category I structures and in their respective divisional raceways.
10. For the Class 1E DC electrical distribution system, independence is provided between Class 1E divisions, and between Class 1E divisions and non-Class 1E equipment.	10. a. Tests will be conducted on the as-built DC electrical distribution system by providing a test signal in only one Class 1E division at a time. b. Inspections of the as-built DC electrical distribution system will be conducted.	10. a. A test signal exists in only the Class 1E division under test in the DC electrical distribution system. b. In the as-built DC electrical distribution system, physical separation or electrical isolation exists between Class 1E divisions. Physical separation or electrical isolation exists between these Class 1E divisions and non-Class 1E equipment.
11. MCR alarms and displays provided for the Direct Current Power Supply are as defined in Subsection 2.13.3.	11. Inspections will be conducted on the alarms and displays for the Direct Current Power Supply.	11. Alarms and displays exist or can be retrieved in the MCR as defined in Subsection 2.13.3.

between wiring and potential sources of disabling mechanical damage consequential to a break downstream of the outboard valve.

(5) Automatic Depressurization System (ADS) and Gravity Driven Cooling System (GDCS) comprising the ECCS have their various sensors, logics, actuating devices and power supplies assigned to divisions, so that no single active failure can disable a redundant ECCS function.

a. The wiring to the ADS solenoid valves within the drywell is run in rigid conduits. The conduits for ADS solenoid A are divisionally separated from ADS solenoid B conduits and contain no other cable. Short lengths of flexible conduit are used to make the final raceway connection to the ADS valve solenoids.

b. The wiring for ADS depressurization squib valves are run in rigid conduits. The conduits are divisionally separated and contain only cable(s) associated with one division of power. Short lengths of flexible conduit are used to make the final raceway connection to the depressurization valve squibs.

c. The wiring to the GDCS squib valve initiators is run in rigid conduits. The conduits are divisionally separated and contain only cable(s) associated with the squib valve initiators. Short lengths of flexible conduit are used to make the final raceway connection to the GDCS squib valve initiators.

(6) Electrical equipment and raceways for safety-related systems are either not located in close proximity to primary steam piping (steam leakage zone), or designed for short-term exposure to the high temperature and humidity associated with a steam leak.

(7) Class 1E electrical equipment located in the suppression pool level swell zone is limited to the suppression pool temperature monitors, which have their terminations sealed such that operation would not be impaired by submersion caused by pool swell or LOCA. These devices are qualified to the requirements of IEEE 323 for the environment in which they are located.

(8) Containment penetrations are arranged so that no design basis event can disable cabling in more than one division. Penetrations do not contain cables of more than one divisional assignment.

(9) Annunciator and computer inputs from Class 1E equipment or circuits are treated as Class 1E and retain their divisional identification up through their Class 1E isolation device. The output circuit from this isolation device is classified as non-Class 1E.

(10) Annunciator and computer inputs from non-Class 1E equipment or circuits do not require isolation devices.

8.3.2 DC Power Systems

8.3.2.1 Description

Completely independent Class 1E (i.e., safety-related) and non-Class 1E (i.e., nonsafety-related) DC power systems are provided. The Class 1E DC system is shown in Figure 8.1-3. The non-Class 1E DC system is shown in Figure 8.1-2.

Eight independent Class 1E 250 VDC systems are provided, two each for Divisions 1, 2, 3 and 4. They provide four divisions of independent and redundant on site sources of power for operation of safety-related loads, monitoring and MCR emergency lighting.

Five independent non-Class 1E DC systems are provided consisting of three 250VDC systems and two 125 VDC systems. The non-Class 1E DC systems supply power for control and switching, switchgear control, TSC, instrumentation, and station auxiliaries.

Refer to Subsection 8.3.4.8 for battery DC cell voltage analysis and ampere hour rating/time.

8.3.2.1.1 Class 1E Station Batteries and Battery Chargers

250V Class 1E DC Systems Configuration

Figure 8.1-3 shows the overall 250 VDC system provided for Class 1E Divisions 1, 2, 3 and 4. Divisions 1, 2, 3 and 4 consist of two separate battery sets for each division. Each set supplies power to selected safety loads for at least 72 hours following a licensing basis event without load shedding. The DC systems are operated ungrounded for increased reliability. Each of the Class 1E battery systems has a 250 VDC battery, a battery charger a main distribution panel, and a ground detection panel. One divisional battery charger is used to supply each group DC distribution panel bus and its associated battery. The divisional battery charger is normally fed from its divisional 480V Isolation Power Center. The main DC distribution bus feeds the local DC distribution panels, UPS inverter, and DC power center. Each division has a standby charger to equalize the battery charging of that division.

The four safety-related divisions are supplied power from four independent Isolation Power Centers. The 250 VDC systems supply DC power to Divisions 1, 2, 3 and 4, respectively, and are designed as Class 1E equipment in accordance with IEEE Std 308 and IEEE 946 (Reference 8.3-1). The Class 1E DC system is designed so that no single active failure in any division of the 250 VDC system results in conditions that prevent safe shutdown of the plant while a division has been taken out of service for maintenance.

The plant design and circuit layout of the DC systems provide physical separation of the equipment, cabling, and instrumentation essential to plant safety. Each 250VDC battery is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each division of the DC distribution system is located in an area separated physically from the other divisions. All the components of Class 1E 250 VDC systems are housed in Seismic Category I structures.

Class 1E Batteries

In divisions 1, 2, 3 and 4 the two 250 volt Class 1E batteries per division are each rated for 72-hour station blackout conditions. The DC system minimum battery terminal voltage at the end of the discharge period is 210 volts. The maximum equalizing charge voltage for Class 1E batteries is 280VDC.

The Class 1E batteries have sufficient stored capacity without their chargers to independently supply the safety-related loads continuously for the time periods stated above. Each distribution circuit is capable of transmitting sufficient energy to start and operate all required loads in that circuit. The batteries are sized so that the sum of the required loads does not exceed 80% of the battery ampere-hour rating, or warranted capacity at end-of-installed-life with 100% design demand. Batteries are sized for the DC load in accordance with IEEE Standard 485 (Reference 8.3-2). The battery banks are designed to permit the replacement of individual cells.

The Class 1E batteries meet the qualification requirements of IEEE 535 (Reference 8.3-3), and are installed in accordance with IEEE 484 (Reference 8.3-9).

Class 1E Battery Chargers

The Class 1E battery chargers are full wave, silicon-controlled rectifiers. The housings are freestanding, NEMA Type 1, and are ventilated. The chargers are suitable for float charging the batteries. The chargers operate from a 480 volt, 3 phase, 60 Hz supply. The power for each divisional battery charger is supplied by that division's dedicated Isolation Power Center. The standby battery charger is used to equalize either of its associated divisional batteries off-line, or as a replacement to the normal charger associated with that battery.

Standby chargers are supplied from the same Isolation Power Center as the normal charger.

Each battery charger is capable of recharging its battery from the design minimum charge to 95% of fully charged condition within 24 hours while supplying the full load associated with the individual battery.

The battery chargers are the constant voltage type, adjustable between 240 and 290 volts, with the capability of operating as battery eliminators. The battery eliminator feature is incorporated as a precautionary measure to protect against the effects of inadvertent disconnection of the battery. The battery chargers are designed to function properly and remain stable on the disconnection of the battery. Variation of the charger output voltage is less than ± 1 percent with or without the battery connected. The maximum output ripple for the charger is 30 millivolts RMS with the battery, and less than 2% RMS without the battery.

The battery charger's output is of a current limiting design. The battery chargers are designed to prevent their AC source from becoming a load on the batteries because of power feedback from loss of AC power. The battery charger's output voltage is protected against over voltage by a high voltage shutdown circuit. The over voltage protection feature is incorporated to protect equipment from damage caused by high voltage. When high voltage occurs, the unit disconnects the auxiliary voltage transformer, which results in charger shutdown. Loss of charger input voltage and charger shutdown is alarmed in the control room.

Ventilation

A safety-related ventilation system is not required for the batteries to perform their safety-related functions. However, battery rooms are ventilated by a system designed to remove the minor amounts of gas produced during the charging of batteries. The system is designed to preclude the possibility of hydrogen accumulation (see Subsection 9.4.6).

Inspection, Maintenance, and Testing

An initial composite test of the onsite DC power systems is a prerequisite to initial fuel loading. This test verifies that each battery capacity is sufficient to satisfy a safety load demand profile under the conditions of a LOCA and loss of preferred power. Battery capacity tests are conducted in accordance with IEEE Std. 450. These tests ensure that the battery has the capacity to meet safety load demands.

In-service tests, inspections, and resulting maintenance of the DC power systems including the batteries, chargers, and auxiliaries are specified in the plant-specific Technical Specifications.

Station Blackout

The station blackout scenario (defined in 10 CFR 50.63, Regulatory Guide 1.155 and Appendix B to SRP 8.2) includes the complete loss of all offsite and onsite AC power, but not the loss of available AC power buses fed by station batteries through inverters, as with the ESBWR. The ESBWR 10 CFR 50.2 Design Bases rely upon battery power to achieve and maintain safe shutdown for 72 hours. The batteries are adequately sized for the station blackout loads. The station blackout safety analysis is provided in Subsection 15.5.5.

8.3.2.1.2 Non-Class 1E Station Batteries and Battery Chargers

125V and 250V Non-Class 1E DC Systems Configuration

Figure 8.1-2 shows the overall 125V and 250V non-Class 1E DC systems. The DC systems are operated ungrounded for increased reliability. Each of the DC systems has battery, a battery charger, a standby battery charger, main DC distribution panel, and ground detection panel. The main DC distribution buses feed the local DC distribution panels, UPS inverter and/or DC motor control center.

The plant design and circuit layout of the non-Class 1E DC systems provide physical separation of the equipment, cabling and instrumentation associated with the load groups of non-Class 1E equipment. Each 125V and 250 VDC battery is separately housed in a ventilated room apart from its charger, distribution, and ground detection panels. Equipment of each load group of the DC distribution system is located in an area separated physically from the other load groups.

The non-Class 1E DC power is required for standby lighting, control and switching functions such as the control of 6.9 kV and 480V switchgear, DC motors, control relays, meters and indicators.

Non-Class 1E Batteries

The 125 volt non-Class 1E batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 volts per cell at 25°C (77°F). The DC system minimum battery terminal voltage at the end of the discharge period is 105 volts. The maximum equalizing charge voltage for 125V batteries is 140 VDC.

The 250 volt non-Class 1E batteries are sized for 2-hour duty cycles at a discharge rate of 2 hours, based on a terminal voltage of 1.75 volts per cell at 25°C (77°F). The DC system minimum battery terminal voltage at the end of the discharge period is 210 volts. The maximum equalizing charge voltage for 250V batteries is 280 VDC.

The non-Class 1E batteries have sufficient stored capacity without their chargers to independently supply their loads continuously for at least 2 hours. Each distribution circuit is capable of transmitting sufficient energy to start and operate all required loads in that circuit.

The batteries are sized so that the sum of the required loads does not exceed 80% of the battery ampere-hour rating, or warranted capacity at end-of-installed-life with 100% design demand. The battery banks are designed to permit replacement of individual cells .