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8.0 Electric Power

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8.1 Introduction

An off-site power system and an onsite power system are provided for each unit at the Oconee Nuclear Station to supply the unit auxiliaries during normal operation and the Reactor Protection System and Engineered Safeguards Protection Systems during abnormal and accident conditions.

Each Oconee unit has five available sources of power to the Engineered Safeguards Systems as shown in Figure 8-1. These are:

1. The 230 kV transmission system and/or the 525 kV transmission system
2. Two Keowee hydro units
3. The 100 kV transmission system
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The normal arrangement is for three of these to serve any or all units and to be switched in the preferential order as follows: (1) the 230 kV transmission network through the unit startup transformers, (2) one Keowee hydro unit through an overhead 230 kV circuit, and (3) the other Keowee hydro unit through an underground circuit.

Whenever the underground circuit from Keowee is unavailable, a circuit from the 100 kV transmission network can be connected to the Standby Buses and serve as an emergency power source.

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8.1.1 Utility Grid System and Interconnections

Duke Power Company is an investor-owned utility serving the Piedmont region of North Carolina and South Carolina. The Duke transmission system consists of interconnected hydro plants, fossil-fueled plants, combustion turbine units, and nuclear plants supplying energy to the service area at various voltages up to 525 kV. Duke is a member of the Virginia-Carolina (VACAR) Subregion of the Southeastern Electric Reliability Council (SERC). All the companies in the region are interconnected such that the combined networks operate as a single, integrated system.

Protocols between Oconee and the transmission system operator (TSO) have been established to ensure grid voltage is monitored and maintained in accordance with the guidance of Generic Letter 2006-02, "Grid Reliability and the Impact on Plant Risk and the Operability of Off-site Power." Transmission load flow analysis tools (analysis tools) are used by the TSO to assist Oconee in monitoring grid conditions to determine the operability off-site power systems under plant technical specifications (TSs). In addition, off-site power restoration procedures are in accordance with Section 2 of NRC Regulatory Guide (RG) 1.155, "Station Blackout."

A detailed description of the off-site power system is provided in Section 8.2.

8.1.2 On-site Power Systems

The on-site power system for each unit consists of the main generator, the unit auxiliary transformer, the startup transformer, the Keowee Hydro Station, the Standby Shutdown Facility (SSF), the batteries, CT4 transformer, and the auxiliary power system. Under normal operating conditions, the main generator supplies power through the isolated phase bus to the unit auxiliary transformers. The unit auxiliary transformers are connected to the bus between the generator disconnect link and the associated unit step-up transformer for all three Units. During normal operation, station auxiliary power is supplied from the main generator through the unit auxiliary transformer or start up transformers. During startup, during shutdown, and after shutdown station auxiliary power is supplied from the 230 kV system through the startup transformer or auxiliary transformer via back charge (Reference Section 8.2.1.3 Second Paragraph).

The on-site power systems and their interconnection with the off-site power system are shown in Figure 8-1.

The on-site power systems are described in detail in Section 8.3.

8.1.3 Safety-Related Loads

The loads that require electric power to perform their safety function are identified in Table 8-1.

8.1.4 Design Bases

The design of the electrical systems for this three unit nuclear station is based on providing the required electrical equipment and power sources to assure continuous operation of the essential station equipment under all applicable conditions.

A safety related valve with electric motor actuation will be assigned a safety related power source if the valve is required to respond immediately in an accident scenario in order to assure safe shutdown of the plant or to mitigate the consequences of the accident. Valves (with electric motor actuators) which are not required to respond immediately for accident mitigation or safe shutdown may be powered from safety related sources when readily available, or from non-safety related, non-loadshed sources when the following conditions exist: a) the valve actuator is equipped with manual override to allow manual actuation, b) the environment in the immediate vicinity of the valve will allow operator access, c) adequate time exists for operator intervention to be effective, and d) operator training is such that there is reasonable expectation that operator intervention will occur when required.

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8.2 Off-site Power System

8.2.1 System Description

8.2.1.1 Utility Grid System

The primary transmission system of Duke consists of a highly integrated 525 kV and 230 kV loop network. Underlying the primary transmission system is an extensive 100 kV sub-transmission network integrated into the primary system by means of 230/100 kV tie stations.

8.2.1.2 525 kV Switching Station

Unit 3 generates electric power at 19 kV that is fed through an isolated phase bus to a unit step-up transformer where it is stepped up to the transmission voltage of 525 kV. From the step-up transformer an overhead transmission line feeds power to the 525 kV switching station through two circuit breakers connecting the unit to the 525 kV transmission network.

Three transmission lines connect to the Oconee 525 kV Switching Station; one circuit goes east-northeast to Jocassee, one east to the Newport Station and one southeast to the Georgia Power Co. In addition, a 230/525kV autotransformer connects the 525 kV switching station to the 230 kV switching station. The 525 kV buses, disconnect switches, and circuit breakers are arranged into a breaker-and-a-half configuration.

8.2.1.3 230 kV Switching Station

Unit 1 and Unit 2 also generate electric power at 19 kV that is fed through an isolated phase bus on each unit to its own step-up transformer, where it is stepped up to the transmission voltage of 230 kV. From each step-up transformer, an overhead transmission line feeds power to the 230 kV switching station through two circuit breakers connecting each unit to the 230 kV transmission network. Eight transmission lines connect to the Oconee 230 kV Switching Station; two circuits are installed east-northeast to North Greenville, four east-southeast to Central, and two north-northwest to Jocassee. See Figure 8-1 and Figure 8-2 for arrangement of lines in the Oconee Station and on the site.

The 230 kV buses, disconnect switches, and circuit breakers are arranged into a breaker-and-a-half configuration.

Each unit is provided with two physically independent circuits from the switching station. One is the circuit from the 230 kV switching station through the startup transformer, which is designed to be available within a few seconds following a loss of coolant accident. The second circuit is the path from the switchyard through the main step-up transformer, the main generator bus and the unit's auxiliary transformer with the generator disconnected from the main bus. This second circuit was originally required to be available following a hypothetical loss of all station power and the resulting LOCA in time to prevent fuel and reactor coolant pressure boundary degradation. This ceased to be a requirement following the 1993 UFSAR update in which the safety analysis of the hypothetical loss of all station power was replaced with a station blackout analysis for Oconee. The station blackout analysis outlines the use of the Standby Shutdown Facility to mitigate a station blackout while preventing a loss of coolant accident. The second circuit is currently used during refueling as an additional power feed for the shutdown unit(s) from the 230 kV switchyard. Both the Unit 1 and Unit 2 auxiliary transformers and the Unit 1, Unit 2, and Unit 3 startup transformers are rated at 45/60MVA and have two isolated secondary windings rated 6900 volts and 4160 volts each. The Unit 3 auxiliary transformer is rated at 42/56/70MVA and has two isolated secondary windings rated 6900 volts and 4160 volts each.

The normal power supply to a unit's auxiliary load can be provided through the unit auxiliary transformer connected to the generator bus. This source of power is available except when:

1. The generating unit is in a normal shutdown condition, or
2. There is a malfunction or failure preventing continued operation of the reactor-turbine-generator-auxiliary transformer combination.

If power is not available from the unit's generator through the unit's auxiliary transformer or operating preference is to use the start-up transformer, power is supplied to the unit through its startup transformer fed from either or both of the buses in the 230 kV switching station. Power to the startup transformer can flow through the 230 kV switching station from any one of thirteen supplies. These include eight 230 kV transmission circuits, two nuclear generating units if operating, two hydroelectric units and the 525 kV switching station. Each unit's auxiliary startup transformer is sized to carry full load auxiliaries for one nuclear generating unit plus the engineered safeguards equipment of another unit. In addition, each unit's startup transformer can backup another unit's startup transformer through emergency startup buses and dual isolating disconnect switches. Refer to Section 8.4.2 for limitations and effects on system voltage adequacy.

This source of power is available except when:

1. Both of the 230 kV buses in the switching station are unavailable, or
2. There is a 230 kV system blackout, no nuclear generating unit is running, and neither hydro unit is capable of supplying power through the 230 kV connection; or
3. The startup transformer fails or their connection to the 230 kV switching station fails and the unit's auxiliary transformers or their backfeeding circuitry are not available.

8.2.1.3.1 230 kV Switching Station Degraded Grid Protection

Two channels of Degraded grid protection (DGP) are provided to assure that the degradation of the voltage from off-site sources does not adversely impact the safety function of safety-related systems and components. Each channel of this system, upon indication of inadequate voltage, will provide an alarm to alert control room personnel of the existence of inadequate voltage in the 230 kV switchyard. If an ES signal is sensed by the DGPS, while the voltage is sustained below acceptable levels, the DGPS will initiate an isolation of the 230 kV switchyard (yellow bus) and start Keowee so that the on-site emergency overhead power path is available. The non-ES operating units will not be affected by this action. The other units will continue to operate since their generators remain connected to the red bus. It is anticipated that any degradation of the voltage in the 230 kV switchyard will not last for an extended period of time. It is recognized that the voltage in the yard needs to be maintained above acceptable levels, and corrective measures would be taken to assure that timely actions are taken to restore the voltage.

There are three single-phase undervoltage relays installed to monitor the switchyard voltage on X, Y, and Z Phase of the 230 kV yellow bus. Each of the undervoltage relays is connected to one of three single-phase coupling capacitor voltage transformers. The setpoint of the undervoltage relays considers the minimum analyzed switchyard voltage and the accumulative tolerances of the undervoltage relays and the voltage sensing devices. A time delay is provided to override transients in the off-site system and prevent unnecessary actuation of this protection system.

Voltage analyses indicate that several 208V and 600V MOV and continuous-duty motor terminal voltages are below the acceptance criteria during the worst-case accident with degraded grid conditions. The analyses conclude that (a) several MOV's could stall due to the low supply voltage and (b) 4160V bus undervoltage relays could trip, thereby disconnecting the EDS from the transmission grid and repowering it from the standby on-site emergency power source (i.e. a Keowee Hydro Unit). As an operating option, by load shedding several large non-safety related 4160V loads, safety related equipment performance can be improved during an accident with degraded grid conditions.

Normally, the Oconee 230 kV switchyard operates at satisfactory rated voltage when one or more Oconee Units are on-line. If all three units are off-line (including a single on-line Unit that trips), a minimum switchyard voltage is not guaranteed.

In the event of a design basis accident, the accident Unit trips off-line. This reduces switchyard voltage due to the lost generation. As an operating preference, by tripping several large non-safety related loads, the available margin can be maintained above an acceptable level. If the load shed circuitry is unavailable or fails to operate, the Keowee Units will start and re-power the safety related EDS as designed.

8.2.1.4 100 kV Switching Station

Whenever there is inadequate power from the generating units, the 230 kV switching station and the hydro units, power is available to the standby power buses either directly from the 100 kV Central Tie Substation or from Lee Steam Station via a 100 kV transmission line connected to 12/16/20 MVA Transformer CT5 located on the opposite side of the station from the 230 kV facilities. This single 100 kV circuit is connected to the 100 kV transmission system through the substation at Central located eight miles from Oconee. Central Substation is connected to Lee Steam Station twenty-two miles away through a similar 100 kV line. If an emergency occurs that would require the use of the 100 kV transmission system, this line can either be isolated from the balance of the transmission system to supply emergency power to Oconee from Lee Steam Station, or emergency power can be supplied directly from the 100 kV system from the Central Tie Substation.

Degraded voltage protection is provided to protect the essential plant auxiliaries from low voltage on the 100 kV system grid. Logic and relaying is installed to alert the operator via an annunciator any time the secondary voltage of transformer CT-5 decreases to such a low value that, if it was the power supply to the main feeder buses and a LOCA/LOOP occurred, proper equipment operation could not be assured. This logic and relaying also "arms" the supply breakers from transformer CT-5 to 4160V Standby Buses #1 & 2 after a time delay. Logic and relaying is also provided which automatically trips the supply breakers from transformer CT-5 to 4160V Standby Buses #1 & 2 if the breakers have previously been armed and the voltage decreases to the trip setpoint.

Located at Lee Steam Station are two 41 MVA combustion turbines. One of these combustion turbines can be started in one hour and connected to the 100 kV line. Transformer CT5 is sized to carry all the engineered safeguards auxiliaries of one unit plus the shutdown loads of the other two units. This source of power is available except:

1. When the 100 kV line or transformer is out of service, or
2. Temporarily after a complete system blackout of all transmission facilities.

8.2.1.5 Switching Station 125 Volt DC Power Systems

The 230 kV switchyard and 525 kV switchyard are served by independent 125V DC power systems. Each switching station DC system consists of two 125 volt DC, two conductor, metalclad distribution center assemblies; three battery chargers; and two 125 volt DC batteries. The 230 kV switchyard 125V DC system is typical of this arrangement and is shown in Figure 8-7. A bus tie with breakers is provided between the switchgear bus sections to "backup" a battery when it is removed for servicing. One standby 125 volt dc battery charger is also provided between the two 125 volt dc batteries for servicing. One battery supplies power through panelboards for primary control and protective relaying, and the second battery supplies power through panelboards for backup control and protective relaying. Dual feeds from the redundant panelboards are provided to each Power Circuit Breaker (PCB) for closing and tripping control. Separate dual trip coils are provided for each PCB. For the 230 kV switching station PCBs isolating diodes are provided for the redundant power feeds to the common closing coil circuit.

8.2.2 Analysis

Reliability considerations to minimize the probability of power failure due to faults in the network interconnections and the associated switching are as follows:

1. Redundancy is designed into the network interconnections by installing two full capacity transmission circuits for each connection to the 230 kV grid.
2. The two single 230 kV transmission circuits are installed on the same line of double circuit towers. Each line of double circuit towers is separated a safe distance from the others and in most cases installed over a different route.
3. One of the circuits on a line of 230 kV transmission towers is insulated at a higher insulation level than the other, thus minimizing the probability of double outages due to flashovers.
4. Each circuit is protected from lightning and switching surges by an overhead electrostatic shield wire and in addition, lightning arresters are installed at both terminals.
5. The breaker-and-a-half switching arrangement in the 230 kV and 525 kV switching stations includes two full capacity main buses which feed each circuit through a circuit breaker connected to each bus. Completely redundant primary and backup relaying is provided for each circuit along with circuit breaker failure backup protection. These provisions permit the following:
   a. Any circuit can be switched under normal or fault switching without affecting another circuit.
   b. Any single circuit breaker can be isolated for maintenance without affecting any circuit.
   c. Short circuits of a single main bus will be isolated without interrupting service to any circuit.
   d. Short circuit failure of the tie breaker will result in the loss of its two adjacent circuits until it is isolated by disconnect switches.
   e. Short circuit failure of a bus side breaker will result in the loss of the associated bus until it is isolated.
   f. Failure of either the primary protective relaying or the backup protective relaying will not result in the loss of circuit protection.

   With the above protection features, the probability of loss of more than one source of 230 kV or 525 kV power from credible faults is low; however, in the event of an occurrence causing loss of all the 230 kV and 525 kV connections, the station is supplied from one or more of three sources of power, i.e., the two hydro units or the 100 kV line supplied by either the Lee combustion turbines or the Central Tie Substation.
6. The 100 kV transmission line is located above the level of any flood that is postulated on the Keowee River. On the Duke system, wind and ice loadings are more severe than seismic loadings and govern the structural design of transmission lines, including this 100 kV line.
7. As shown in Table 8-2, the 125 volt DC switching station power systems are arranged such that a single fault within a system does not preclude the protective relaying and control in the affected switching station from performing its intended functions.

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8.3 Onsite Power Systems

8.3.1 AC Power Systems

8.3.1.1 System Descriptions

The station distribution system consists of various electrical systems designed to provide reliable electrical power during all modes of station operation and shutdown conditions. The systems are designed with sufficient power sources, redundant buses, and required switching to accomplish this. Engineered safeguard equipment for each unit is arranged onto three load group buses such that the loss of a single bus section for any reason results in only the loss of equipment fed from that bus leaving redundant equipment to perform the same function. In general, the equipment related to unit operation is connected to its respective unit auxiliary electrical buses, whereas equipment common to and serving all units is distributed between the three unit auxiliary electrical buses. The control of power sources and switching for Oconee 1 and 2 is accomplished from the Oconee 1 and 2 control room while control of power sources and switching for Oconee 3 is from the Oconee 3 control room.

8.3.1.1.1 Keowee Hydro Station

The Keowee Hydro Station contains two units rated 87,500 kVA each, which generate at 13.8 kV. Upon loss of power from the Oconee generating unit and 230 kV switchyard, power is supplied from both Keowee units through two separate and independent routes.

One route is a 4000 ft. underground 13.8 kV cable feeder to 12/16/20 MVA Transformer CT4 which supplies the redundant 4160 volt standby power buses. The underground emergency power feeder is arranged with double air circuit breakers (equipped with low air pressure monitoring switches) so that it can be connected to either Keowee generator bus. The connection to the generator bus is made with metal-enclosed bus. This under ground feeder is selected at all times to one hydroelectric generator on a predetermined basis and is automatically energized along with Transformer CT4 whenever that generator is in service in either emergency or normal mode. The underground feeder and associated transformer are sized to carry full engineered safeguards auxiliaries of one unit plus auxiliaries for safe shutdown of the other two units.

The second route is a 230 kV transmission line to the 230 kV switching station at Oconee which supplies each unit's startup transformer. Each Keowee generator is connected to a common 230 kV stepup transformer through a 13.8 kV metal-enclosed bus and synchronizing air circuit breaker equipped with low air pressure monitoring switches.

Each Keowee unit is provided with its own automatic startup equipment located in separate cubicles within the Keowee control room. The initiation of emergency startup is accomplished by control signals from either Oconee control area. Normal startup of either unit is by operator action while emergency startup is automatic. Both units are started automatically and simultaneously and run on standby on either of three conditions: 1) external grid trouble protection system actuation, 2) engineered safeguards actuation or 3) main feeder bus monitor undervoltage actuation. If the units are already operating when any of the above conditions occur, they are separated from the network (and momentarily from the underground path) and continue to run on standby until needed. Each unit's voltage regulator is equipped with a volts-per-cycle limiting feature which permits it to accept full emergency power load as it accelerates from zero to full speed within 23 seconds from receipt of the emergency startup initiation signal.

On normal automatic startup, each unit is automatically connected and supplies power to the Oconee 230 kV switching station through the stepup transformer by its respective generator air circuit breaker. This is accomplished by the automatic synchronizing equipment of each unit. On emergency automatic startup, both units are started; the unit with the underground feeder selected to it supplies that feeder and the other unit is available to supply the Oconee 230 kV switching station. If there is a system disturbance, this unit is connected automatically to the Oconee 230 kV Yellow Bus only after the Oconee 230 kV Yellow Bus is isolated automatically from the system and the preset time delay has elapsed. Redundant External Grid Trouble Protective Systems are provided to isolate the 230 kV switching station on failure of the external transmission network. Therefore, on loss of the external transmission network, both of the Keowee hydro units can provide emergency power to any of the Oconee units through either the 230 kV switching station to the unit's respective startup transformer or the underground feeder and Transformer CT4 at Oconee.

Power from the hydro units is available except when:

1. Both units are out of service, or
2. There is a coincident failure of the underground feeder circuit and a complete outage of the 230 kV feeder circuit through the switching station.

   The Standby Shutdown Facility (SSF) consists of standby systems for use in extreme emergency conditions. Following the loss of all normal and emergency power, on-site and off-site, the SSF diesel electric generating unit will be manually started by initiating the start signal from the SSF Control Panel in the SSF. The SSF Electrical Power System supplies power necessary to maintain hot shutdown of the reactors of each unit, in the event of loss of power from all other power systems.

The SSF is described in detail in Section 9.6. The SSF's role in SBO coping is discussed in Section 8.3.2.2.4.

8.3.1.1.2 6900 Volt Auxiliary System

The 6900 volt auxiliary system for each unit is designed to supply electric power to the 9000 horsepower reactor coolant pump motors. This system is arranged into two bus sections. Both bus sections feed into two switchgear bus sections, each feeding two motors. Each switchgear bus supplies one motor for each of the two reactor coolant piping loops. Either the unit auxiliary or the startup transformer is capable of feeding both switchgear buses. During startup, shutdown and after shutdown, the switchgear buses are supplied from the startup transformer. During normal operation, the switchgear buses are supplied from the unit auxiliary transformer. Normal bus transfers between the two sources are initiated at the discretion of the operator from the control room, while emergency transfer from the unit auxiliary to the startup transformer is initiated automatically by protective relay action. Normal bus transfers used on startup or shutdown of a unit are “live bus” transfers, i.e., the incoming source feeder circuit breaker is closed onto the energized bus section and its interlocks will trip the outgoing source feeder circuit breaker which results in transfers without power interruption. Emergency bus transfers used on the loss of the normal unit source are rapid bus transfers, i.e., the outgoing source feeder circuit breaker is tripped and its interlocks close the incoming source feeder circuit breaker which results in a transfer within a maximum of nine cycles. An exception to this occurs when the main generator has been supplying in-plant loads while separated from the switching station. In this instance, there is a transfer delay when the normal unit source is lost.

The 6900 volt auxiliary system as shown in Figure 8-1 and Figure 8-3 is similar in arrangement for each of Oconee 1, 2, and 3.

8.3.1.1.3 4160 Volt Auxiliary System

The 4160 volt auxiliary system for each unit is arranged into a double bus - double circuit breaker switching arrangement. The three power sources, (1) the unit's auxiliary transformer, (2) the startup transformer and (3) the standby power buses, feed each of the main feeder buses by this double circuit breaker arrangement. Each of the two redundant main feeder buses provide power to each of the three redundant engineered safeguards switchgear bus sections that serve the engineered safeguards auxiliaries. The engineered safeguards auxiliaries are arranged so that a failure of any single bus section does not prevent the respective systems from fulfilling their protective functions.

The 4160 volt auxiliary system as shown in Figure 8-1 and Figure 8-3 is similar in arrangement for all three units.

On loss of their normal sources of power the 4160 volt main feeder buses are transferred as described for the 6900 volt system to alternate sources of power in the following preferential sequence:

1. Transfer to startup transformer where:
   a. Power is supplied from the 230 kV transmission system, or
   b. Power is supplied from one of the two Keowee hydro units via the 230 kV switchyard.
2. Transfer to 4160 volt standby power buses where:
   a. Standby power is supplied from one Keowee hydro unit via the 13.8 kV underground feeder, or
   b. Standby power is supplied from the 100 kV transmission line.

The control system is designed to prevent the paralleling of two sources during the switching operation and is similar to the transfer systems Duke has used for many years in their fossil-fired plants.

Upon loss of the unit auxiliary transformer source and startup transformer source, and in the absence of an engineered safeguards (ESG) signal, the following occurs:

The turbine-generator and reactor are tripped and the main feeder buses become deenergized. Control power is still available from the dc and vital power systems.

Both of the Keowee hydro units are started and the selected unit will be automatically connected to the standby power buses from which power can be supplied to the shutdown auxiliaries.

The non-essential loads are shed.

The equipment required to bring the reactor to a hot shutdown is energized.

Logic and control circuits will be fed without interruption from dc sources and vital power buses.

In the event of a loss of coolant accident requiring engineered safeguards action, the following action takes place:

Both Keowee hydro units are started immediately. The unit not selected to the underground feeder is run on standby and connected to the 230 kV Yellow Bus when the bus is isolated.

The underground circuit from Keowee becomes automatically energized as the hydro unit to which it is selected is started and breaker control interlocks are satisfied.

The 4160 volt redundant main feeder buses of the unit with the accident are switched to the emergency power sources in the preferential order as described in Section 8.3.1.1.3 (1) and (2).

The engineered safeguards of the unit with the accident are started and the non-essential loads are shed when power is unavailable from the normal or startup sources.

In the event the external transmission network is lost, the following action takes place:

Both Keowee hydro units are started immediately and the unit not selected to the 13.8 kV underground feeder is connected automatically to the 230 kV Yellow Bus by closing its respective generator circuit breaker and the 230 kV Power Circuit Breaker (PCB)-9 when the 230 kV Yellow Bus is isolated from the system network.

The 230 kV Switchyard Yellow Bus is isolated automatically from the system grid by energizing the dual trip coils of the 230 kV PCBs 8, 12, 15, 17, 21, 24, 26, 28, and 33.

The startup transformers No. CT1, CT2, and CT3 remain connected to the 230 kV switching station.

The 13.8 kV underground circuit from Keowee becomes energized as the hydro unit to which it is connected is started.

In the event of an accident and the simultaneous loss of the external transmission network, the engineered safeguard switchgear buses are supplied emergency power through both 4160 volt main feeder buses from either the 4160 volt startup transformers through their respective feeder breakers or from both of the redundant standby power buses. The standby power buses receive emergency power from either the Keowee Hydro Station or the 100 kV transmission line described in Section 8.3.1.1.3 (2). In the event of a Loss of Coolant Accident (LOCA) any breakers supplying the engineered safeguards loads are closed automatically. In the event of a LOCA and the simultaneous loss of both the normal auxiliary source and the startup source, the non-essential load breakers are tripped. Redundant engineered safeguards load-shedding logic equipment assures positive shedding of non-essential equipment by energizing separate trip coils provided in their circuit breakers. Redundant engineered safeguards actuation channels initiate closing of the essential equipment feeder breakers.

In the event of a Unit reactor trip and a simultaneous engineered safeguards channel 1 or channel 2 actuation, the load shed circuit can be activated to trip several large non-safety related loads.

Each Oconee Unit has a LOCA Load Shed Logic Scheme that, in the event of LOCA when the main turbine trips and offsite power is available, trips the following non-essential 4160 volt load breakers.

1. Three (3) of four (4) Condenser Circulating Water Pumps
2. Two (2) of three (3) Condensate Booster Pumps
3. Two (2) of three (3) Hotwell Pumps
4. All four (4) Heater Drain Pumps

LOCA Load Shed ensures adequate 4kV (and below) system voltages for safety-related equipment during a LOCA or inside-containment main steam line break with offsite power available via the startup transformer.

8.3.1.1.4 600 Volt Auxiliary System

Each unit's 600 volt auxiliary system is similar and arranged into multiple bus sections. Each bus section is fed from a separate load center transformer which is connected to one of the three 4160 volt switchgear bus sections. Various 600 volt non-engineered safeguard motor control centers are located throughout the station to supply power to equipment within the related area. The three engineered safeguards load centers and associated motor control centers as shown in Figure 8-4 are redundant and are supplied independently from the three 4160 volt engineered safeguards load buses. Load center X8 and X9 have an alternate feeder with manual transfer to be used when the normal source of power is not available. Each engineered safeguard motor control center has an alternate feeder with manual transfer to be utilized only for maintenance. No common failure mode exists for this system.

8.3.1.1.5 208 Volt Auxiliary System

For each unit, a system is provided to supply instrumentation, control, and power loads requiring unregulated 208Y/120 volt ac power. It consists of motor control centers, distribution panels, and transformers fed from 600 volt motor control centers.

The redundant engineered safeguards 208 volt motor control centers for a unit are shown in Figure 8-4. Each of these motor control centers have redundant supply feeders from separate transformers and redundant 600 volt motor control centers. The feeder breakers have mechanical interlocks and manual transfers.

The 208 volt auxiliary system is similar in arrangement for each of the three units.

8.3.1.1.6 Tests and Inspections

Remote startup of the Keowee generators is provided in each of the control rooms of the nuclear station. Provisions are made in the control rooms to manually initiate an emergency start of both of the two hydroelectric generators connecting the generator to the nuclear station's 4160 volt buses. Testing of this system may be scheduled any time the Keowee hydro units are not running.

The 100 kV, 230 kV and 525 kV circuit breakers are inspected, maintained and tested as follows:

1. 100 kV transmission line circuit breakers are tested on a routine basis.
2. 230 kV and 525 kV transmission line circuit breakers are tested on a routine basis. This is accomplished without removing the transmission line from service.
3. 230 kV and 525 kV switchyard generator circuit breakers may be tested with the generator in service.

Transmission line protective relaying is tested on a routine basis.

Generator protective relaying is tested when the generator is off-line.

The 4160 volt circuit breakers and associated equipment are tested in service by opening and closing the circuit breakers in a manner that does not interfere with the operation of the station. The circuit breakers may be "jacked out" to a test position and operated without energizing the circuits, if necessary.

The 600 volt circuit breakers, motor contactors, and associated equipment are tested in service by opening and closing the circuit breakers or contactors so as not to interfere with operation of the station.

Emergency transfers to the various emergency power sources are tested on a routine basis to prove the operational ability of these systems. The 4160 volt Main Feed Bus can be transferred between power sources or associated normal, startup, and standby circuit breakers on one bus can be "jacked out" into test position and initiated manually for an emergency transfer test.

8.3.1.2 Analysis

The emergency electric power system provided for each nuclear generating unit possesses certain inherent design features which improve its reliability over limited capacity split-bus arrangements usually provided in nuclear power plants.

The basic design criterion for the electrical portion of the emergency electric power system of a nuclear unit, including the generating sources, distribution system, and controls is that a single failure of any component, passive or active, will not preclude the system from supplying emergency power when required. Special provisions have been employed to accomplish this which include a double bus - double breaker distribution system, redundant circuit breaker trip coils and circuits, diverse protective relaying for each circuit breaker, redundant load shedding and transfer logic equipment, physical separation and other features.

The reliability afforded by the split bus concept is included in the design of the double bus - double breaker system employed here. Consideration has been given to the capacity of the emergency power sources, the method of switching, redundancy utilized and the protective features. For example, the electrical system together with the sources of electric power which are installed to supply emergency power to a nuclear unit possesses the following design features:

1. Each electric power source is extremely large for the requirements. For example, each of the redundant on-site Keowee hydroelectric units is rated 87,500 kVA while the maximum combined load demand on one nuclear unit with a LOCA and the other two nuclear units with a LOOP is 15,971 kVA as shown in Table 8-1. The Keowee underground and Lee emergency power sources are the smallest due to the power limitations of Transformers CT-4 and CT-5 which have a maximum continuous rating of 22,400 kVA. The significant effect of these large sources of emergency power is that a greater number of plant auxiliaries may be run and used to help cope with an incident as well as shutdown and maintain the other nuclear units in safe shutdown conditions.

2. The Keowee hydroelectric units are inherently reliable sources of power as proven by years of operating experience with similar generating units. Since they are stored energy type machines, their ability to start is very reliable.

   Except for the penstock, and cooling water supply pipe to the first valve, shared air supply, static inverter and regulation, standby battery charger, 4160V and 600V underground power supply to Keowee through CX, 230 kV main transformer, fire protection system, ACB air system, each unit is entirely independent of the other, consisting of its own turbine, governor system, generator, exciter, voltage regulator, generator circuit breaker, synchronizing equipment, protective relaying, automatic startup control equipment, manual controls, unit dc control battery, etc.

   If one hydro unit is out for maintenance, the other unit is available for service. The two units are served by a common tunnel-penstock, and unwatering for tunnel or scroll case maintenance will make both units unavailable. Based upon Duke's experience since 1919 with a hydro station similarly arranged, it is expected that unwatering frequency will be about one day per year plus four days every tenth year.

   During all periods when the Keowee units are available for emergency power service, the Keowee Hydro Headgate will be rigidly fastened to assure that failure of the hoist system will not permit the gate to move into the closed position.

   The independent Keowee units, along with the alternate circuits, provide the required redundancy to assure reliable emergency power. Storage capacity of the Keowee reservoir and naturally occurring minimum streamflow are such that the generating units can provide continuous emergency power following an accident. The Keowee reservoir, between its normal elevation and maximum planned drawdown, has sufficient storage which, when combined with minimum recorded streamflow on the Keowee River will permit a hydro unit to carry continuously one nuclear unit's emergency auxiliary loads for 126 days.

The failure analysis covering the Keowee Hydro Station is outlined in Table 8-3.

3. Each electric power distribution system is designed with redundant full capacity buses to match the capacity of the large emergency power source. This thereby provides two continuous sources of supply from the two full capacity main feeder buses to each of the three engineered safeguards switchgear buses.

4. Reliability of the engineered safeguards switchgear buses is assured by the following protective features:

   a. 4160 V engineered safeguards (ESG) switchgear bus overload and bus fault conditions are protected for by both ground fault overcurrent relays and phase overcurrent relays. These relays are provided on each ESG switchgear bus breaker and function to open the associated breaker to isolate the ESG switchgear bus from the main feeder buses, thereby maintaining the integrity of the main feeder buses.

   b. Each ESG switchgear feeder breaker is also included in the zone of protection afforded by the main feeder bus differential current relays which would function to isolate a faulted breaker from any source of supply.

   c. Each ESG switchgear feeder breaker is provided with breaker failure protective relaying. This feature will initiate action to isolate the breaker from any source of supply if the breaker fails to open upon a protective relay trip. The maximum equipment this would remove from service is one ESG switchgear bus and one main feeder bus, leaving two ESG switchgear buses and the other main feeder bus to supply the required loads which are sufficient to perform the intended safety functions.

   d. Each ESG switchgear feeder breaker is provided with redundant trip coils, supplied from separate dc supplies, assuring positive trip action.

   With the above protective features plus their metalclad construction and the physical separation maintained, failure of any one of the three redundant ESG switchgear buses or components will not affect the ability of the other two ESG switchgear buses to supply their engineered safeguards loads.

5. Reliability of the main feeder buses and the standby buses is assured by the following protective features:

   a. Each main feeder bus and each standby bus is protected independently by differential current relays. These relays will sense any fault condition in the zone between the source side of the incoming bus feeder breakers to the load side of the outgoing feeder breakers. The outgoing feeder breakers on the standby bus are the breakers connecting to the main feeder buses and they have overlapping differential protection from both buses. The outgoing feeder breakers of the main feeder buses are the feeder breakers to the engineered safeguards switchgear buses. If a fault condition occurs, the relays will function to isolate the affected bus from all sources of supply by opening all circuit breakers associated with that bus. The other redundant bus still provides the required power to all three engineered safeguards switchgear buses.

   b. Each feeder breaker to each of the buses is protected with phase overcurrent and ground fault overcurrent protective relaying. These relays function to open the breaker and isolate the main feeder bus from the power source upon the occurrence of these overcurrent conditions. This thereby maintains the integrity of the power source and allows the continued supply of power to the other bus and all three engineered safeguards switchgear buses. The comparable condition on a split bus concept would cause the loss of one engineered safeguards bus.

c. Each feeder breaker is also provided with breaker failure protective relaying. This feature will initiate action to isolate the breaker from any source of supply if the breaker fails to open on a protective relay trip. The maximum loss on this condition would be the connected source of supply and the associated bus. The other bus would transfer by the redundant transfer logic to the alternate source of supply and continue supplying power to all three engineered safeguards switchgear buses. The maximum loss under the split bus concept would not only be the source of supply, but also the associated engineered safeguards switchgear bus.

d. Each feeder breaker is provided with redundant trip coils supplied from separate dc supplies, assuring positive trip action.

With the above protective features, their metal-enclosed construction and their physical separation, failure of any one of the redundant bus sections or components will not affect the ability of the other buses to supply the engineered safeguards loads.

6. The emergency power sources are independent of each other and switched on to the main feeder buses such that this independency is maintained. Paralleling of emergency power sources is prevented by redundancy in transfer logic equipment and interlocking.

   Redundant systems of emergency power switching equipment are provided to switch the emergency power to the unit's 4160 volt redundant main feeder buses. The redundant transfer logic will seek the most available source of power and when it becomes available close into it. If this source is then subsequently lost, the switching logic and equipment will transfer to the other source automatically if power is available.

7. The seismic and environmental qualification of Class 1E AC Power system equipment is discussed in Section 3.11.2, Qualification Test and Analysis. The NRC issued IE Bulletin 88-10, "Nonconforming Molded-Case Circuit Breakers," on November 22, 1988 and Supplement 1 on August 3, 1989. The purpose of this bulletin and supplement was to alert licensees to the possibility of existence of molded-case circuit breakers which were nontraceable and unqualified for safety-related duties at their nuclear facilities. Accordingly, in responses submitted in letters from H. B. Tucker to the NRC, dated April 3, 1989, April 24, 1989, July 17, 1989, and November 9, 1989, Duke Power Company reported its efforts to identify and locate any suspect circuit breakers, to administratively remove applicable breakers from service/perform appropriate testing and equipment operability evaluations, and to describe programmatic controls to prevent future reoccurrence of this supplier problem. Of the group of suspect breakers, some were eventually designated following qualification inspection for use in non-safety applications. Final removal from service of all suspect breakers used in safety related applications was confirmed in the letter from H.B. Tucker to the NRC, dated August 13, 1990. Closure of DPC actions to satisfy IE Bulletin 88-10 was confirmed in the letter from the NRC to M.S. Tuckman on June 7, 1991.

The failure analysis covering the emergency electrical systems is outlined in Table 8-4.

8.3.1.3 Physical Identification of Safety-Related Equipment

Detailed cable lists are developed for all cables. These cable lists identify each cable by cable type, specific cable routing by tray section number, and termination points. Protective system cables are identified as such on the cable lists. These lists are issued and are used by the field for cable installation. Each cable tray section, excluding cable trays inside the Reactor Building is identified by tags bearing the tray section number assigned to it. Cables required for protective systems are identified as follows:

1. Power and control cables are color coded to identify their use and/or channel association. The color code is as follows:

Gray	Swgr 1TC, 2TC, 3TC Ld Ctr 1X8, 2X8, 3X8 MCC 1XS1, 2XS1, 3XS1, 1XSF, 1XS4, 2XSF, 3XSF, 2XS4, 3XS4 ESG channel 1, 3, 5, & 7 DC Pnlbd 1DIA, 2DIA, 3DIA Vital Pwr Pnlbd 1KVIA, 2KVIA, 3KVIA RPS Ch A AFIS Analog Channel 1
Yellow	Swgr 1TD, 2TD, 3TD Ld Ctr 1X9, 2X9, 3X9 MCC 1XS2, 1XS5, 2XS2, 3XS2, 2XS5, 3XS5 ESG channel 2, 4, 6, & 8 DC Pnlbd 1DIB, 2DIB, 3DIB Vital Pwr Pnlbd 1KVIB, 2KVIB, 3KVIB RPS Ch B AFIS Analog Channel 2
Blue	Swgr 1TE, 2TE, 3TE Ld Ctr 1X10, 2X10, 3X10 MCC 1XS3,1XS6, 2XS3, 3XS3, 2XS6, 3XS6 ESG channel Even-Odd DC Pnlbd 1DIC, 2DIC, 3DIC Vital Pwr Pnlbd 1KVIC, 2KVIC, 3KVIC RPS Channel C AFIS Analog Channel 3 AFIS Digital Channel 1
Orange	DC Pnlbd 1DID, 2DID, 3DID Vital Pwr Pnlbd 1KVID, 2KVID, 3KVID RPS Ch D AFIS Analog Channel 4 AFIS Digital Channel 2
Red	RPS and ESPS Fiber optic communication*

*See Section 8.3.1.4.6.2

2. All cables have their identifying number permanently affixed to both ends.

8.3.1.4 Independence of Redundant Systems

The physical locations of electrical distribution system equipment shown in Figure 8-1, Figure 8-3 and Figure 8-4 are arranged to minimize vulnerability of vital circuits to physical damage as a result of accidents.

8.3.1.4.1 Auxiliary Transformers

Auxiliary transformers, startup transformers, and the 100 kV transformer are located out of doors and physically separated from each other. Transformer CT4, fed from the on-site Keowee Hydro Station is physically separated from the other transformers and located in a Class I enclosure. Reference Section 3.2.1. Surge arresters are used where applicable for lightning protection. All transformers are covered by automatic water spray systems. Transformers are well spaced to minimize their exposure to fire, water, and mechanical damage.

8.3.1.4.2 Switchgear and Load Centers

The 6900 volt switchgear, 4160 volt switchgear, and 600 volt load centers are located in areas to minimize exposure to mechanical, fire, and water damage. This equipment is coordinated electrically to permit safe operation of the equipment under normal and short circuit conditions. Metalclad construction is used throughout for personnel and equipment protection.

The 4160 volt main feeder bus switchgear sections and standby power bus switchgear sections are located in a Class I enclosure. The 4160 volt main feeder busses provide power from the switchgear sections in the Class I structure to the redundant engineered safeguards 4160 volt switchgear and their associated 600 volt load centers and motor control centers, etc., located within the turbine building and auxiliary building below the operating floor level. The engineered safeguards switchgear and load centers are located in areas with separation and protection to minimize exposure to mechanical, fire and water damage. This equipment is coordinated electrically to permit safe operation under normal and short circuit conditions. The engineered safeguards system is of Class I seismic design.

8.3.1.4.3 Motor Control Centers

The 600 volt motor control centers are located in the areas of electrical load concentration. Those associated with the turbine-generator auxiliary system in general are located below the turbine-generator operating floor level. Those associated with the nuclear steam supply system are located in the auxiliary building and mezzanine floor of the turbine building. Motor control centers are located in areas with separation and protection to minimize their exposure to mechanical, fire and water damage. The safety related motor control centers located in the turbine building are qualified for the postulated environment.

8.3.1.4.4 Batteries, Chargers, Inverters, and Panelboards

The 125 volt dc instrumentation and control power system batteries of a unit are physically separated in separate enclosures from batteries of another unit to minimize their exposure to any damage. The battery chargers and associated dc bus sections and switchgear of a unit are located in separate rooms from battery chargers and associated dc bus sections of another unit in the auxiliary building and physical separation is maintained between redundant equipment.

8.3.1.4.5 Metal-Enclosed Bus

Metal-enclosed buses are used for all major bus runs where large blocks of current are to be carried. They are also routed to minimize exposure to mechanical, fire, and water damage.

8.3.1.4.6 Cable Installation and Separation

8.3.1.4.6.1 Cable Installation

Hanger type HC-18, which is one of the most heavily laden hangers, was checked. This Hanger was inspected during the resolution of Generic Letter (GL) 87-02 and found to be seismically adequate per the

Generic Implementation Procedure (GIP-2) for Seismic Verification of Nuclear Plant Equipment, Rev 2, developed by the Seismic Qualification Utility Group (SQUG).

Paragraph(s) Deleted Per 2000 Update.

Overfilled trays were examined and it was determined that section 1ME8 contains 120.4 pounds of cable per linear foot. The tray manufacturers' safe load chart (Reference 2) states that 24 inch tray with 9 inch rung spacing will support a load of 215 pounds per foot with a 2.2 safety factor. The tray used has an ultimate strength of 473 pounds (2.2 x 215). With an existing load of 120.4 pounds the minimum safety factor is 3.8. Therefore, the present tray system is capable of supporting the weight of the cable even with the existing overfilled conditions and the additional fire retardant barriers.

8.3.1.4.6.2 Cable Separation

Control, instrumentation, and power cables are applied and routed to minimize their vulnerability to damage from any source.

Our criteria for routing cables requires that mutually redundant safety related cables be run in separate trays. Trays are spaced vertically in the cable room a minimum of 10 inches apart and in some cases redundant cables are in vertically adjacent trays. It should be pointed out that the cable armors used provide excellent mechanical and fire protection which would not be provided with conventional, unarmored cable systems. An early warning fire detection system has also been provided in this area.

Wire and cables related to engineered safeguards and reactor protective systems are routed and installed to maintain the integrity of their respective redundant channels and protect them from physical damage. Fiber optic wiring (red cable) for the RPS and ESPS, while designated as nuclear safety related, is not required to be separated as a mutually redundant safety channel. This is due to the physical separation provided by its inherent optical design. (Reference SER for RPS/ES.) Power and control cables for redundant auxiliaries or services are run by different routes to reduce any probability of an accident disabling more than one piece of redundant equipment. Floor sleeves are filled with a fire retardant material.

It is our intent wherever physically possible to utilize metallically armored and protected cables systems. By this we mean the use of rigid and thin wall metal conduit, metal sheathed cables (aluminum and other metals), bronze armored control cables, steel interlocked armor, or metallic taped power and control cables, and either interlocked armor, served wire or braided armored instrumentation cables.

Where overfill situations exist in Oconee Units 1, 2, and 3 between vertically adjacent cable trays to the extent that the top cable in the lower tray is within three inches of the bottom cable in the tray immediately above, a one-eighth of an inch fire retardant fiberglass reinforced polyester barrier will be placed between the trays. The fire retardant fiberglass reinforced polyester is used as an insulator and protection mechanism to prevent an electrical short from contacting a nearby tray. This product was used due to its good electric insulating characteristics and its low additional combustible load contribution. These barriers will be attached to the bottom of the upper tray and fitted around cables which may pass through the barrier.

Five inches of cable tray rail to rail separation is provided on installation of cable tray. In Oconee 1, 2, and 3 Cable Rooms where available space will not allow a minimum of five inches rail to rail separation between vertical trays a one-eighth of an inch fire retardant fiberglass reinforced polyester barrier will be attached to the bottom of the top tray as an insulator and protection mechanism.

8.3.1.5 Cable Derating and Cable Tray Fill

8.3.1.5.1 Cable Derating

All cables are selected using conservative margins with respect to their current carrying capacities, insulation properties, and mechanical construction. Cable insulations in the Reactor Building are selected to minimize the effects of radiation, heat, and humidity. Appropriate instrumentation cables are shielded to minimize induced voltage and magnetic interference.

Power cables are derated based on IEEE S-135, ICEA (Insulated Cable Engineers Association), Publication No. P-46-426, recommendations for interlocked armor power cables when installed in cable support systems.

Studies of heating due to I^2R loss in the cables were made. It was determined that the worst case was tray section 1ME8 which contained 322 cables. Cables were classed in three groups: control, control power and instrumentation. Losses were determined by conservative means and were found to be a total of 1.3 watts per lineal foot of tray. Assuming that one cable dissipates 36% of the total heat and that this cable is in the center of a nine inch pile of cable, its maximum temperature would be only 14°C above the ambient cable spreading room temperature, even though the insulation qualities of the cable pile were assumed to be almost perfect. No air flow was assumed through the cables; therefore, the addition of barriers does not alter the heating calculations. Due to the small amount of heat generated and since all cable used in this area is rated 90°C, these temperatures will have no detrimental affect on adjacent cables or on cables in other trays.

Temperature measurements have been made periodically at ten selected locations for the first-year of operation. These locations are where the tray over-fill is the most severe.

Overload protection for cables is very closely related to the basic power and control systems designs. The 4 kV power systems are protected by electro-mechanical overcurrent relays and solid state type ground relays. The relays are selected for the loads protected and the cables are sized based on the maximum currents which these relays should allow without tripping for the loads they are protecting. The 600 volt load centers are used to feed individual motor control centers. The feeder breakers used are furnished with long-time and instantaneous electromechanical or short-time trip elements. Cables to each breaker are sized in coordination with the trip elements selected for that particular breaker. Small motor loads at the 600 volt and 208 volt levels are generally handled through combination motor starters located in motor control centers. Short circuit protection for the load is provided by molded case circuit breakers with magnetic trip devices while overcurrent protection is provided by standard starter overload elements sized for the application. On small engineered safeguard motor loads two of the three overload elements are oversized for cable protection rather than motor protection and are wired in the contactor trip circuit. The third element is sized for motor protection but is wired to alarm only. This is based on the premise that the motor should operate even if motor damage does occur. Cable sizing is based on maximum service factor loading of the motor.

8.3.1.5.2 Cable Tray Fill

Early cable tray requirements were based on types of cable which had been used in the past which were primarily not armored. Armored cable was used at Oconee to achieve better mechanical protection and fire retardance. This caused the trays to fill faster than anticipated and in several locations the fill became excessive. Steps have also been taken to insure that no additional cables are routed through trays which are already overfilled.

The cable tray spacing criterion for those trays containing power cables is based on ICEA, Publication No. P-46-426 recommendations for interlocked armor power cables when installed in cable support systems.

8.3.2 DC Power Systems

8.3.2.1 System Descriptions

For each nuclear unit, two separate dc power systems are provided; namely, a 125 volt dc system provides a source of reliable continuous power for control and instrumentation for normal operation and orderly shutdown for each unit, and a separate 125/250 volt dc system is provided to supply large power loads for each unit. These systems are shown in Figure 8-5 and Figure 8-9. For each Keowee hydro unit, separate and independent dc power systems are provided to assure a source of reliable continuous power for normal and emergency operation. These systems are shown in Figure 8-6.

The adequacy of safety-related dc power was assessed in the Duke response (letter form M.S. Tuckman to USNRC, dated October 9, 1991) to NRC Generic Letter (GL) 91-06, "Adequacy of DC Safey-related Power Supplies," which identified specific alarms/annunciators and indications to monitor dc power and specific procedures for maintenance and surveillance activities. The NRC approved the response in a letter from David B. Matthews to H. B. Tucker, dated June 5, 1992.

8.3.2.1.1 125 Volt DC Instrumentation and Control Power System

For each unit, two independent and physically separated 125 volt dc batteries and dc buses are provided for the vital instrumentation and control power system. The dc buses are two conductor metalclad distribution center assemblies. Three battery chargers are also supplied, with two serving as normal supplies to the bus sections with the associated 125 volt dc battery floating on the bus. The batteries supply the load without interruption should the battery chargers or the ac source fail. Each of the three battery chargers are supplied from the redundant 600 volt ac engineered safeguards motor control centers of each unit. One of these three battery chargers serves as a standby battery charger and is provided for servicing and to backup the normal power supply chargers. A bus tie with normally open breakers is provided between each pair of dc bus sections to “backup” a battery when it is removed for servicing.

Four separate 125 volt dc instrumentation and control panelboards are also provided for each unit. Each panelboard receives its dc power through an auctioneering network of two isolating diode assemblies. One assembly is connected to the unit's 125 volt distribution system and the other assembly is connected to another unit's 125 volt distribution system. The functions of the diode assemblies are to discriminate between the voltage level of the two dc distribution systems, to pass current from the dc system of higher potential to the instrumentation and control panelboard connected on the output of the diode assemblies, and to block the flow of current from one dc distribution system to the other.

Each isolating diode assembly is composed of a series-parallel network of four diodes in each polarity leg of the dc supply to the panelboard it serves. With this series-parallel arrangement of diodes, either an open circuited or short circuited diode can be tolerated without affecting the operability of the diode assembly. The individual diodes are sized for a minimum continuous current of 500 amperes with the maximum panelboard load current is less than 500 amperes. Each diode is also rated for continuous operation with a peak inverse voltage of 800 volts.

Continuous monitoring of each diode is provided in the design of the isolating diode assemblies to allow detection of a shorted or open circuited diode.

An alarm relay, connected to an individual control room annunciator point, is provided for each isolating diode assembly to advise the operator of diode trouble.

Test provisions are included in each isolating diode assembly to allow the in-service checking of the operability of individual diode monitors, and, in addition, to allow the out of service periodic checking of the peak inverse voltage capability of each individual diode. The latter test can be conducted on one isolating diode assembly with the other diode assembly in the network in operation. Breakers on the input and output of each isolating diode assembly are provided for complete isolation during maintenance and testing of an assembly.

8.3.2.1.2 125/250 Volt DC Station Power System

For each unit a separate 125/250 volt dc power system is supplied. Each system consists of three 125/250 volt dc power supply battery chargers, a three conductor, metalclad distribution center assembly, and two 125 volt dc batteries. This arrangement provides 125 volts dc from “P” bus to “PN” bus, 125 volts dc from “PN” bus to “N” bus, and 250 volts dc from “P” bus to “N” bus. Loads on this system are basically the 250 volt dc power loads of units. Each 125 volt dc half of a bus section normally is supplied from one of the 125 volt dc power supply battery chargers with the associated 125 volt dc battery floating on the bus. The batteries supply the load without interruption should the battery charger or the ac source fail. A bus tie with normally open double breakers is provided between the three units' distribution center bus sections to backup a battery when it is removed for servicing. One standby 125 volt dc power supply battery charger is provided between each pair of the 125 volt dc batteries for servicing and to “backup” the normal power supply battery chargers.

8.3.2.1.3 125 Volt DC Keowee Station Power System

For each Keowee hydro unit a separate 125 volt dc power system is supplied. Each system consists of one 125 volt dc power supply battery charger, one 125 volt dc, two conductor, metalclad distribution center assembly and one 125 volt dc battery. A bus tie with normally open double circuit breakers is provided between the two distribution center bus sections to “backup” a battery when it is removed for servicing. One standby 125 volt dc battery charger is also provided between the two 125 volt dc batteries for servicing. The batteries, battery charger and distribution center associated with one unit are located in the same room as those associated with the other unit, but are physically separated from those associated with the other unit by different enclosures. Loss of power to any Keowee instrument and control power supply bus is indicated in the Keowee control room on "statalarm" panels that are powered from an uninterruptible power supply (battery backed inverter). Loss of power to the inverter will be alarmed in the Keowee control room but will not prevent either Keowee unit from performing its safety function.

8.3.2.1.4 120 Volt AC Vital Power Buses

Figure 8-5 shows the arrangement of the 120 volt ac vital power buses. For each unit, four redundant 120 volt ac vital instrument power buses are provided to supply power in a predetermined arrangement to vital power, instrumentation, and control loads under all operating conditions. Each bus is supplied separately from a static inverter connected to one of the four 125 volt dc control power panelboards described in Section 8.3.2.1.1. Upon loss of power from 125 volt dc bus DCA or DCB, the affected inverter is supplied power from a 125 volt dc bus of another unit through dc control power panelboards and transfer diodes of the affected 125 volt dc panelboard. A tie with breakers is provided to each of the 120 volt vital ac buses from the alternate 120 volt ac regulated bus to provide backup for each vital bus and to permit servicing of the inverters. Each inverter has the synchronizing capability to permit synchronization with the regulated buses.

For each unit, each of the four redundant channels of the nuclear instrumentation and reactor protective system equipment is supplied from a separate bus of the four redundant buses. Also for each unit, each of the three redundant channels of the engineered safeguards protective system is supplied from a separate bus of the four redundant buses. The two engineered safeguards actuation power buses are supplied from separate vital power buses.

8.3.2.1.5 240/120 Volt AC Uninterruptible Power System

For each unit, four uninterruptible power systems are provided to supply power.

They are:

1. The unit's Integrated Control System (ICS) power system, which is 120 volt ac, single phase.
2. The unit's Auxiliary Power System (APS) which is 120 volt ac, single phase.
3. The unit's original design Computer Power System (CPS), which is 240/120 volt ac, single phase.
4. The units' new Computer Power System (KOAC), which is 240/120 volt ac, single phase.

Each of these first three systems consist of a static inverter, with redundant 125 volt dc supplies from separate 125 volt dc buses, circuit breakers and distribution panelboards. The fourth system consists of a static inverter with a 250 volt dc supply from a single 250 volt dc bus, circuit breaker, and distribution panelboard. Also, a static transfer switch is provided in each system as a means for automatic transfer of system loads to the alternate ac regulated power system should the inverter become unavailable. The output of each inverter is synchronized with the ac regulated power system through the static switch in order to minimize transfer time from inverter to the regulated supply.

In addition, an automatic transfer switch is provided in the ICS, APS, and CPS power systems as a means for automatic transfer of system loads to the alternate ac regulated power system should the static transfer switch become unavailable.

8.3.2.1.6 240/125 Volt AC Regulated Power System

For each unit, a system is provided to supply instrumentation, control, and power loads requiring regulated ac power. It also serves as an alternate power source to both the vital power panelboards and to the uninterruptible power panel boards. The system consists of two distribution panels, two regulators, and two transformers fed from separate motor control centers. These systems are shown in Figure 8-5.

8.3.2.1.7 Emergency Lighting System

For each unit, two separate emergency lighting systems are provided; namely, an Emergency 250 Volt DC Lighting System and a separate Engineered Safeguards 208Y/120 Volt AC Lighting System. These two systems are separate and distinct.

8.3.2.1.7.1 Emergency 250 Volt DC Lighting System

The 250 Volt DC Lighting System, which is normally de-energized, provides operating level lighting in the control room and lighting at selected areas in the Auxiliary, Turbine, Reactor, Administrative and Service Buildings. The emergency lighting is energized automatically by an undervoltage sensing relay mounted on the individual panelboards located in their associated areas. Control power for the undervoltage transfer circuit is provided from the 250 volt dc station batteries. A test button is also provided at each panelboard to test the operability of the system without affecting normal lighting. All associated lighting units are incandescent.

8.3.2.1.7.2 Engineered Safeguards AC Lighting System

The Engineered Safeguards AC Lighting System, which is normally de-energized, provides lighting in the following parts of the Auxiliary Building: control room, cable room, equipment room, stairs, exits, corridors, hot machine shop, spent fuel pool room, fuel unloading area, decontamination rooms, pump and tank room areas, fan and ventilation rooms of roof elevation, penetration rooms, and purge rooms. The stairs and platforms in the Reactor Building are also provided lighting to enable personnel to leave or enter the entire building. Power is provided from two engineered safeguards 600 volt ac control centers through two 600/208Y/120 volt ac dry type transformers which in turn feed each of two panelboards located in the equipment room area. The engineered safeguard lighting is energized automatically by undervoltage sensing relays monitoring the normal 600 volt ac feeder voltage.

Upon loss of power, the undervoltage relay for the Engineered Safeguards Lighting (ESL) system drops out and aligns the engineered safeguards lighting system to the safety-related bus. When Keowee starts and supplies power to the station, the under voltage relay is picked up by the recovery of power to Units 1, 2, 3 load centers X5, X6, and X7 and therefore the ESL lights never illuminate. The ESL emergency lighting system is still functional, but is not expected to illuminate and thus not tested.

8.3.2.1.8 DC and AC Vital Power System Monitoring

Failure and/or misoperation of all dc and ac vital power system equipment is being monitored on two local alarm annunciators located in the equipment room near most of the vital equipment. Several variables within each piece or redundant group of equipment are being monitored on one of the local panels, with any alarm from each group being retransferred to a common group alarm in the control room. Although not considered a failure or misoperation, ground conditions on the vital dc system are provided an alarm in the control room. The control room alarms alert the operator if an alarm condition occurs on any piece or group of equipment, or if power is lost to the local alarm monitoring equipment.

The DC bus tie breakers, battery breakers and standby charger breaker position indication contacts; the standby charger trouble contact; and the computer, ICS and auxiliary inverter isolating diode trouble contacts are monitored directly in the control room.

The other vital alarms are divided into two separate and independent monitoring systems. Alarms for equipment which have battery 1CA for their primary source of power are maintained physically and electrically separate from battery 1CB powered equipment. For example, the distribution center, isolating diodes, breakers, panelboards, inverters and transfer switches associated with battery 1CA are alarmed on local and remote annunciators which are physically and electrically separated from the annunciators being used for monitoring battery 1CB associated systems.

Specifically, the variables being monitored locally with a composite alarm from each of the 17 groups being taken to the control room are as follows:

Group 1 and 11 for each of the two dc buses

Charger trouble

Charger output breaker tripped

Bus voltage low

Group 2, 3, 4, 5, 12, 13, 14, 15 for each of eight isolating diodes

Fuse blown

Diode failure

Input breaker open

Output breaker open

Feeder breaker open

Group 6, 7, 16, 17 for each of four vital inverters and panelboards

Inverter input voltage low

Inverter output voltage low

Bypass voltage low

Inverter bypassed

Panelboard voltage low (60%)

Group 8, 18, 19 for computer, ICS and auxiliary inverters and panelboards

Inverter input voltage low

Inverter output voltage low

Bypass voltage low

Inverter bypassed

Panelboard voltage low (60%)

8.3.2.2 Analysis

The 125 Volt DC Instrumentation and Control Power System and the 125 Volt AC Vital Power System are designed such that upon loss of power supplies no interactions exist between Reactor Protection Systems, Engineered Safeguards Protection Systems, and control systems that would preclude these systems from performing their respective functions. Also, any interactions between units as a result of the loss of power supplies does not preclude the safety and control systems of any unit from fulfilling their function. This is verified by safety analyses and is shown in Table 8-5, Table 8-6, and Table 8-7.

The ungrounded dc system has a ground detector with a manually switched backup to indicate when there is a ground existing on any leg of the system. A ground on one leg of the dc system will not cause any equipment to malfunction. Simultaneous grounds on two legs of the system may cause all energized equipment to drop out if the grounds are of sufficiently low resistance. This may be momentary if the grounded circuit is cleared by its circuit breaker or sustained if the grounded circuit is not cleared by its circuit breaker.

Each battery is sized to carry the continuous emergency load for a period of one hour in addition to supplying power for the operation of momentary loads during the one hour period. The Station Blackout (Section 8.3.2.2.4) coping strategy which manually strips non-essential loads from the 125 Volt I&C Power System within 30 minutes into the event allows for the operation of the equipment required during the scenario for four hours.

In normal operation the batteries are floated on the buses, and assume load without interruption on loss of a battery charger or ac power source.

The lead-acid batteries are tested to prove their ampere-hour capacity. Inservice periodic checks of the status of each cell is made through battery hydrometer log readings and cell voltage. Temperature readings are used to adjust hydrometer readings.

The seismic and environmental qualification of Class 1E dc power system equipment is discussed in Section 3.11.2, Qualification Test and Analysis. The NRC issued IE Bulletin 88-10, "Nonconforming Molded-Case Circuit Breakers," on November 22, 1988 and Supplement 1 on August 3, 1989. The purpose of this bulletin and supplement was to alert licensees to the possibility of existence of molded-case circuit breakers which were nontraceable and unqualified for safety-related duties at their nuclear facilities. Accordingly, in responses submitted in letters from H.B. Tucker to the NRC, dated April 3, 1989, April 24, 1989, July 17, 1989, and November 9, 1989, Duke Power Company reported its efforts to identify and locate any suspect circuit breakers, to administratively remove applicable breakers from service/perform appropriate testing and equipment operability evaluations, and to describe programmatic controls to prevent future reoccurrence of this supplier problem. Of the group of suspect breakers, some were eventually designated following qualification inspection for use in non-safety applications. Final removal from service of all suspect breakers used in safety related applications was confirmed in the letter from H.B Tucker to the NRC, dated August 13, 1990. Closure of DPC actions to satisfy IE Bulletin 88-10 was confirmed in the letter from the NRC to M.S. Tuckman on June 7, 1991.

8.3.2.2.1 Single Failure Analysis of the 125 Volt DC Instrumentation and Control Power System

As shown in Table 8-5, the 125 Volt DC Instrumentation and Control Power System is arranged such that a single fault within either system does not preclude the Reactor Protective System, Engineered Safeguards Protective System, and the engineered safeguards equipment from performing their safety functions.

8.3.2.2.2 Single Failure Analyses of the 125 Volt DC Keowee Station Power System

The 125 Volt DC Keowee Station Power System is arranged such that a single fault within either unit's system does not preclude the other unit from performing its intended function of supplying emergency power.

8.3.2.2.3 Single Failure Analysis of the 120 Volt Vital Power Buses

The 120 Volt Vital Power System is arranged such that any type of single failure or fault will not preclude the Reactor Protective System, Engineered Safeguards Protective System, and engineered safeguards equipment from performing their safety functions. There are four independent buses available to each unit, and single failure within the system can involve only one bus. A single failure analysis is presented in Table 8-6.

8.3.2.2.4 Station Blackout Analysis

Station Blackout (SBO) is the hypothetical case where all off-site power and both Keowee hydro-electric units are lost. Electrical power is available immediately from the battery systems and within 10 minutes from the SSF diesel generator. This event was originally included in FSAR section 15.8.3. As documented in the NRC Safety Evaluation Report (SER) dated March 10, 1992 and the NRC

Supplemental SER dated December 3, 1992, Oconee Nuclear Station is in compliance with 10 CFR 50.63 and conforms to the guidance of NUMARC Report 8700 and Regulatory Guide 1.155. This regulation requires that a licensed nuclear power plant demonstrate the ability to achieve safe shutdown from 100% reactor power by ensuring containment integrity and adequate decay heat removal for a calculated duration. The licensee must also demonstrate that the required equipment be able to withstand the resulting operating environment. The temperature of the control room and other areas where extensive manual operations occur, shall not exceed habitability requirements of 120°F. Station blackout is not a design basis event. Therefore, the SBO scenario is not concurrent with any design basis event or single failures.

Oconee is capable of coping with a SBO by the following means:

1. The SBO duration is 4 hours by application of NUMARC 8700 guidance.
2. The SSF diesel generator is the alternate AC (AAC) source and is available within 10 minutes. The SSF diesel generator must be manually started from the SSF control room, and the capability of plant operators to access the SSF control room, manually start the diesel generator, and supply electric power within 10 minutes of recognition of an SBO event has been demonstrated by testing.
3. The SSF Auxiliary Service Water system is the design basis source of decay heat removal. Actuation of the Emergency CCW System is not required since the inventory in the CCW piping is sufficient for 4 hour operation of the SSF/ASW system.
4. The non-essential inverters (KI, KU, and KX) are manually stripped from the Vital 125VDC System within 30 minutes to ensure that the Class 1E batteries have sufficient capacity for the 4-hour SBO coping duration and recovery actions, and to reduce the electrical heat loads of the unit control complex. Refer to FSAR Selected Licensee Commitment 16.8.1. The resulting temperature in the unit control room does not exceed the habitability requirement of 120°F. Therefore, command and control remain in the unit control room to allow completion of restoration procedures as required in the Supplemental SER dated December 3, 1992.
5. Containment isolation valves fail closed on loss of air or power, can be manually closed, or have diverse closure ability from the SSF as required in NUMARC 8700.
6. Restoration of power is accomplished by manual closure of switchgear breakers at Switchgear control panel.

Stripping the non-essential inverters from the 125VDC system will make power available to the TDEFWP and its associated controls in the unit control room for 4 hours. Although its operability is limited to 2 hours due to the volume of the associated nitrogen supply. Notably, the TDEFWP is not required for the 4 hour coping period since the SSF ASW system is the licensing and design basis commitment for decay heat removal during the SBO event.

The 4 hour coping duration is derived from NUMARC 8700 based on meteorological data, grid stability, switchyard features, and availability/reliability of emergency power sources. A program to control SSF availability/reliability has been implemented to ensure at least a value of 95% as stated in the Supplemental SER. The program is based on the largest single contributor of SSF unavailability, which is unwatering of Unit 2 CCW intake piping. This is based on the fact that Unit 2 CCW intake piping supplies suction to the SSF Auxiliary Service Water pump, the diesel engine cooling and the SSF HVAC. SSF availability is also dependent on the reliability of Keowee, the SSF batteries, the SSF diesel generator and supporting systems. Additionally, controls are implemented so that planned maintenance on the SSF and Keowee does not occur simultaneously.

8.3.3 References

1. Unistrut Corporation General Engineering Catalog No. 6, 1966, Page 11.
2. Unistrut Corporation Catalog KUR4P-2, Page 16.

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8.4 Adequacy of Station Electric Distribution System Voltages

8.4.1 Analysis

Each offsite power source was analyzed to the onsite distribution system under maximum and minimum load conditions with the offsite power sources at maximum and minimum anticipated voltages. The analysis included the transient effects on the Class 1E equipment from starting a large Class 1E and non-Class 1E load. The maximum voltage expected at the 4kV bus is slightly higher than the equipment rating. However, this voltage does not have detrimental effects on plant loads or motor feeder circuits. When voltage drops are accounted for, the maximum equipment terminal voltage is within the equipment rating. In anticipation of future growth, changes have been incorporated to maintain bus and terminal voltages within acceptable limits specifically, relocating loads to various buses, delaying the start time of certain large motors, and shedding non-safety related loads in anticipation of unique conditions. The minimum analyzed bus voltages shown in the most current analysis are high enough to account for feeder voltage drops that exist between the bus and the loads. The minimum equipment terminal voltage is within the equipment rating. It has been established that the 4160 volt, 600 volt and 208 volt emergency loads will operate within allowable voltage limits when supplied from the offsite power system.

Tests were performed in accordance with NRC guidelines for verification of voltages and currents for the Unit 3 distribution system while the unit auxiliary transformer of that unit supplied 100% of the normal full power operating loads. The measured voltage values were compared with calculated voltage values, and in all cases, the measured values were acceptably close to the analyzed voltage values (0.21-0.28% for the 4 kV buses; within 0.33% for 600 volt buses; and within 1.05 to 1.73% for the 208 volt buses). This test verifies the accuracy of the analysis for the steady-state condition. The verification tests on Unit 3 are applicable to Units l and 2 also, since they employ identical equipment and distribution systems. Therefore, no separate tests are required on Units 1 and 2.

8.4.2 Conclusions

1. The voltages are within the operating limits of Class IE equipment for projected combinations of plant load and offsite power grid conditions provided one startup transformer is used for one unit.
2. Spurious separation from the offsite power system due to the operation of voltage protective relays will not occur (with the offsite grid voltage within its expected limits) as a result of starting safety loads.
3. It has been determined (by analysis) that no potential for either a simultaneous or consequential loss of both offsite power sources exists.

8.4.3 References

1. J. F. Stolz (NRC) to H. B. Tucker, Letter, Review of Adequacy of Station Electric Distribution System Voltages for Oconee Nuclear Station, Units Nos. 1, 2, and 3 (enclosing NRC SER and EG&G TER) Washington, D.C., March 1983.

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