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ELECTRIC POWER

8.1 INTRODUCTION

8.1.1 UTILITY GRID DESCRIPTION

The Union Electric Company (UE) system consists of interconnected hydroelectric, nuclear, and fossil-fuel plants supplying electric energy over a 345/230/161/138-kV transmission system. Figure 8.1-1 is a map of the local utility grid surrounding Callaway as it existed at the time of initial plant licensing. This system is also an integral part of the midwest interconnected utility grid, with interconnections to numerous utility companies in the region. UE is also a member of the Gateway subregion of the SERC Reliability Corporation, one of eight regional entities under the North American Electric Reliability Corporation (NERC).

8.2 OFFSITE POWER SYSTEM

8.2.1 DESCRIPTION

8.2.1.1 Transmission Network

The UE system supplies the offsite ac power required for start-up, normal operation, and safe shutdown of the nuclear unit.

The offsite power sources to the 345-kV Plant Site Switchyard consists of two 345-kV circuits from the Montgomery Substation about 21 miles to the northeast near New Florence, a 345-kV circuit from the Bland Substation, and a 345-kV circuit from the Loose Creek Substation, as shown in Figure 8.2-1. The Bland Substation is located on the south side of the existing 345-kV Labadie-Franks-3 transmission line right-of-way, north of Owensville, Missouri and west of State Highway 19 and is about 29 airline miles to the south of the plant. The Loose Creek Substation is located east of Loose Creek, Missouri and south of State Highway 50 and is about 22 airline miles to the southwest of the plant. The power line terminations at the Montgomery, Bland, and Loose Creek Substations are illustrated on Figures 8.2-2, 8.2-3, and 8.2-4, respectively. The integration of the lines into the interconnected system is also indicated. This arrangement provides two physically-separated offsite transmission lines comprised of four 345-kV circuits. The nearest distance between a Loose Creek and a Montgomery line is the point where they attach to the switchyard arbors. The distance between the outside phases of these lines at this point is 216 feet.

The Montgomery, Bland, and Loose Creek Substations are part of the UE transmission network as described in Section 8.1. The Montgomery and Bland 345-kV circuits are installed on double-circuit steel-tower structures, entirely. The Loose Creek line is installed on a combination of double-circuit steel-towers and wooden H-frame structures. The first segment of the line to Montgomery Substation runs northeasterly on a new 200-foot right-of-way to a junction with the existing Montgomery-Guthrie 161-kV transmission line; at this point it turns easterly and uses an additional 150 feet of right-of-way to adjoin the existing right-of-way to Montgomery Substation, crossing the 161-kV line to enter Montgomery Substation from the west. The line from the plant site south to Bland Substation is on a 200-foot right-of-way, except for the part which parallels a Central Electric Power Cooperative 161-kV line on a 150-foot wide right-of-way. The line crosses the Missouri and Gasconade Rivers. Two 69-kV and two 161-kV transmission lines are also crossed in passage. The second line from the plant site south to Loose Creek Substation shares double-circuit steel-tower structures with the Bland line until just after the Missouri River crossing. The Loose Creek line then continues, separately, southerly on wooden H-frame structures to the Loose Creek Substation.

The transmission lines are not subject to any unusual conditions, and construction is consistent with Union Electric's established practices. The transmission lines and their associated structures interconnecting the plant and the two substations with the

transmission system are designed to successfully withstand the loading requirements for environmental conditions prevalent in the area related to terrain, soils, wind, temperature, lightning, and floods, to minimize the possibility of failure.

8.2.1.2 Plant Site Switchyard and Connections to Onsite Distribution System

The 345-kV Callaway Switchyard consists of circuit breakers, disconnect switches, buses, transformers, and associated equipment. The switchyard is arranged in a breaker-and-a-half configuration as shown in Figure 8.2-5.

A 345/13.8-kV Safeguard Transformer is connected directly to each 345-kV bus through a disconnect switch which is capable of interrupting magnetizing current. Safeguard Transformer A is a three-winding transformer rated 60/80/100-MVA which is identical to the Startup Transformer and can be used to replace it if necessary. Safeguard Transformer B is a two-winding transformer rated 30-MVA. Each transformer has two low side breakers connected so that either transformer may supply via underground duct a 13.8/4.16-kV Engineered Safety Feature (ESF) Transformer at the plant. The Safeguard Transformers are sized so that either Transformer A or B has the capacity to handle the design shutdown or the design basis LOCA load. The 13.8-kV breakers are electrically interlocked so that the low side windings of the Safeguard Transformers cannot be connected together.

Another offsite supply consists of a 345-kV overhead circuit from the switchyard to the Start-up Transformer. The capacity of the 345-kV circuit to the Start-up Transformer is more than adequate to supply the total connected loads on the Start-up Transformer. A tap off of one of the secondaries of this Start-up Transformer supplies the second ESF Transformer. The two ESF transformers with their associated capacitor banks and supply circuits from the 345-kV Switchyard provide two independent sources of offsite power for the Class 1E buses.

Each ESF and associated automatic load tap changer Transformer is rated 12/16-MVA and has adequate capacity to supply the maximum loads of both safety-related systems simultaneously during normal and abnormal operating conditions, accident conditions or plant shutdown conditions. Their associated capacitor banks provide voltage correction for the NB busses if required.

The 13.8 kV cables to the ESF Transformers are designed for 16MVA at 95% voltage. The secondary cables are sized for 8MVA per 4 kV Class 1E Bus at 95% voltage. The ampacity and group derating factors of the cables are in accordance with the manufacturer's recommendations and IPCEA publication P46-426 for cables in duct banks and maintained spaced trays. The cable ampacities are based on a maximum conductor temperature of 90 degrees C, 100 percent load factor and all cables fully loaded.

The second feeder from the Safeguard Transformer will be used to serve site facilities such as the water intake, demineralizer, service building, stores building, 345-kV switchyard station service, etc., as described in Section 8.3 and shown in Figure 8.3-1.

The physical arrangement of the 345-kV switchyard will be as shown in Figures 8.2-7, 8.2-8, 8.2-9, 8.2-10, and 8.2-11. The dotted lines in Figure 8.2-7 indicate space for future additions to the switchyard which would be installed if required by system conditions.

8.2.1.3 Compliance With Design Criteria and Standards

8.2.1.3.1 Transmission Lines

The transmission lines for the 345-kV circuits comply with Union Electric's current design standards and criteria for 345-kV double-circuit steel-tower lines and wooden H-frame tower lines which are presently operating as part of its transmission system without any adverse environmental effects. These designs comply with the requirements of the national Electrical Safety Code (NESC) as well as applicable design data prepared by the American Society of Civil Engineers (ASCE), the Edison Electric Institute (EEI) and accepted standards of other recognized organizations.

All the materials incorporated into these transmission lines conform to the latest applicable specifications and requirements of the American Society for Testing Materials (ASTM), the American National Standards Institute (ANSI), the National Electrical Manufacturer's Association (NEMA), and applicable standards of other recognized organizations. This assures that each component has been designed and manufactured to provide maximum operating safety and minimum possibility of adverse environmental effects.

NRC General Design Criterion 17 "Electric Power Systems" is satisfied by using two transmission line rights-of-way which approach the plant site from different directions, and by transmission line designs which have a proven operating record, thus minimizing the possibility of a simultaneous failure of both lines.

8.2.1.3.2 Switchyard

This switchyard has been designed in accordance with the following industry standards: (1) Institute of Electrical and Electronics Engineers, Inc. (IEEE), (2) American National Standards Institute (ANSI), (3) National Electrical Manufacturers Association (NEMA), (4) American Society for Testing and Materials (ASTM) and (5) National Electric Safety Code (NESC).

The following analysis demonstrates how the 345-kV Plant Site Switchyard complies with NRC General Design Criteria 17 and 18 of 10 CFR Part 50.

Criterion 17 - Electric Power Systems

In addition to the features detailed in Sections 8.2.1.1 and 8.2.1.2, compliance with Criterion 17 is further demonstrated by the following:

1) Any one of the 345-kV transmission circuits is capable of carrying the auxiliary load.

2) The 345-kV system is protected from lightning and switching surges by lightning-protective equipment and by overhead static lines.

3) The design of the 125-volt dc system for the switchyard provides for two independent dc systems. Each of the two systems consists of a separate 125-volt dc battery, a battery charger, and a distribution system. Cable separation is maintained between the two systems from the batteries to the distribution cabinets. A single failure caused by a malfunction of either of the two 125-volt dc systems will not affect the performance of the other system. The ability of the switchyard to supply offsite power to the plant will not be affected by the complete loss of either of the two 125-volt dc systems. The surveillance of battery charger operation and battery voltage for each battery system is provided by alarms monitored in the plant control rooms.

Alarm windows are provided on the plant control room annunciator for the following switchyard conditions:

1. A common window for AC or DC supply trouble.

2. A common window for dc control power failure to the transformer differentials and breaker failure protection circuits.

3. A common window for switchyard annunciator trouble or oscillograph trouble.

4. A common window for loss of carrier signal on any 345 kV circuit.

5. A common window for safeguard transformer A or B trouble.

6. A common window for breaker troubles such as low gas pressure, loss of auxiliary power, etc., for each individual 345 kV breaker.

7. Individual windows for the opening of each 345 kV breaker for any reason (manual or relay trip).

8. Individual windows for 345 kV bus protection trip for each bus.

The common windows are broken down to individual alarm functions on annunciators in the switchyard.

In addition to these alarms, each 345 kV breaker has two trip coils (one on each of the two non-class 1E switchyard dc power systems with its own associated battery) which are each monitored by a red (breaker closed) indicating light on the main control board. There are indicating ammeters on the main control board that indicate the ac load current through the 345 kV breakers. Indicating and recording 345 kV bus voltmeters are also located on the main control board.

The plant surveillance of the switchyard is supplemented by remote indication in the System Load Dispatcher office in St. Louis of Callaway 345 kV bus voltage and frequency, 345 kV line MW and MVAR flows, breaker position indication, motor operated disconnect switch position, loss of carrier or tone signal, and loss of voltage on the dc control power circuit.

4) Two isolated 13.8 kV supplies are provided to the switchyard, one from the plant bus and one from the Safeguard Transformer bus. The ac load can be carried by either of the two power supplies, and the loss of one feeder will not jeopardize continued operation of the switchyard equipment. Protective relaying and tripping for 345-kV circuit breakers is supplied by battery and is independent of the ac auxiliary supply.

5) The 345-kV Switchyard circuit breakers are rated 3-kA, and are 3-pole, 60-Hz oilless dead tank type, using arc-quenching sulfur hexaflouride gas for current interruption. The interrupting capability is 50-kA symmetrical rms at 362-kV. the current interrupting time is two cycles on a 60-Hz basis. Closing and latching current capability is 80-kA rms symmetrical.

   345-kV circuit breakers V45, V51, and V85, Figure 8.2-5, are pneumatically operated with each circuit breaker having its individual motor driven air and gas compressors and associated storage receivers. Tripping is accomplished by spring energy which is compressed during the closing operation. Primary and back-up heaters connected to isolated power supplies are provided to keep the sulfur hexaflouride gas in its thermally insulated tank from liquefying during cold weather. Sufficient gas and air storage is provided with each circuit breaker for three successive complete close/open operations, starting at normal working pressure, without necessity for compressor operation between or during these close/open operations. The three poles of the breaker are operated simultaneously by one pneumatic operating mechanism through mechanical linkages.

   345 kV circuit breaker V41, V43, V53, V55, V71, V75 and V81, Figure 8.2-5, are operated by stored energy springs. The closing springs are charged by a-c motors fed from the switchyard primary or backup supply systems. Tripping is accomplished by trip spring energy. These

springs are compressed during the closing operation. The closing and trip springs are thus charged after each close operation. Given a loss of power to both the primary and backup power supplies, one close/open operation of the circuit breaker is available. Each of the three poles of the breaker are operated simultaneously by separate operating mechanisms. A pole disagreement relay will automatically trip the circuit breaker in the event that a pole is not in alignment with the other poles of the circuit breaker. Tank heaters are connected to the primary or backup power supply to keep the sulfur hexaflouride gas from liquefying during cold weather.

Each of the circuit breakers has redundant trip coils termed primary and secondary. The primary and secondary relays and their associated trip coils are on separate dc control power circuits to provide a high degree of reliability. Separate current transformers are provided for primary and for secondary relaying.

6) For reliability and operating flexibility, the substation design is basically a breaker-and-a-half arrangement, with breaker-failure backup protection. The above provisions permit the following:

   a) Any transmission line can be cleared under normal or fault conditions without affecting any other transmission line.

   b) Any circuit breaker can be isolated for maintenance without interrupting the power or protection to any circuit.

   c) Short circuits on a section of bus will be isolated without interrupting service to any items of equipment other than those connected to the faulted bus section.

<u>Criterion 18 - Inspection and Testing of Electrical Power Systems</u>

The 345-kV circuit breakers are inspected, maintained, and tested on a routine basis. This can be accomplished without removing the generators, transformers, or transmission lines from service. The transmission line protective relays are tested on a routine basis. This can be accomplished without removing the transmission lines from service. The protective relays for the generators and the main and unit auxiliary transformers are tested on a routine basis when the generators are off-line.

8.2.2 ANALYSIS

8.2.2.1 <u>Results of Steady State and Transient Stability Analyses</u>

Load flow and transient stability analyses demonstrate the ability of the grid to provide uninterrupted synchronous alternating current to the 345-kV Plant Site Switchyard for the following conditions:

a. With any one of the 345-kV transmission circuits out of service, a sustained three-phase fault on any other 345-kV circuit cleared in primary clearing time of 0.05 seconds.

b. A sustained three-phase fault occurring simultaneously on both circuits of a double-circuit 345-kV transmission line between the Plant Site Switchyard and the Union Electric grid cleared in primary time of 0.05 seconds.

c. A sustained three-phase fault on any one of the 345-kV transmission circuits between the Plant Site Switchyard and the Union Electric grid cleared in breaker-failure back-up clearing time of 0.175 seconds. Tripping of the nuclear unit is inherent if the cleared "stuck-breaker" is located common to the unit as well as the faulted transmission circuit. (See Figure 8.2-5)

Load-flow and transient stability studies show that the interconnected system is stable, and 345-kV Plant Site Switchyard power is available to the onsite systems after a trip of the nuclear unit. Power to replace that lost form the nuclear unit is supplied by the interconnected system and Union Electric's internal reserve.

While the transient stability tests listed do not cover all possible contingencies, they do give an indication of transmission strength and the probability of maintaining normal voltage conditions at the Plant Site Switchyard 345-kV buses.

The physical separation and reliability of connections between the Plant Site Switchyard and the onsite power systems are indicated in the preceding Section 8.2.1.2 "Plant Site Switchyard and Connections to Onsite Distribution System."

Steady state design capability of the offsite power supply to the onsite power system exceeds the onsite power requirements. (Calculated voltage angles are less than 10 degrees and compare to a steady state stability limit of 90 degrees).

Therefore, the above shows that there is a minimum probability of losing all electric power to the onsite systems as a result of or coincident with the loss of power generated by the nuclear unit, the loss of a power supply from the switchyard or the loss of power from the onsite electric power supplies.

8.2.2.2 Grid Availability

Grid availability is contingent on performance of the 345-kV circuits supplying the Plant Site Switchyard. These circuits are connected to two substations in the integrated system which are each fed by at least two additional supplies.

The power supply from the grid to the Montgomery and Bland 345-kV Substations (the major transmission substations supplying the offsite power) are designed to assure that for the loss of a single element (generator, circuit, tower line, transformer, bus, etc.) the

system must operate without loss of load, with no lines loaded above emergency ratings, and without having any excessively low voltages.

In addition, simulated testing assures that for extreme, yet credible, contingencies as outlined in MAIN Guide No. 2 - Reliability Criteria (such as loss of all facilities on a single right-of-way, loss of power plant and all associated transmission, or loss of a circuit and tower) the bulk power supply network or any major portion thereof does not suffer a cascading areawide breakup and collapse.

The expected electrical performance of the 345-kV transmission lines constructed for the nuclear plant is outlined below.

The Union Electric system calculated trip-outs per 100 R.O.W. miles per year due to lightning flashover on 345-kV double-circuit steel towers having bundled-conductor circuits ranges from 0.5 to 1.2 per circuit. This is based on the established isokeraunic level of 50 thunderstorm days per year and a tower footing ground resistance in the range of 15 to 20 ohms. Design criteria are based on maintaining the probability at 1.0 or less flashover per 100 miles per year, for lightning.

Union Electric's historical outage rate for all types of 345-kV circuits is 2.08 trip-outs per 100 circuit-miles per year. These outages are caused primarily by storms (lightning, wind, and ice, etc.) but include all other causes as well. Average duration of these 345-kV circuit outages is 3.14 hours.

Transmission grid availability on the Union Electric system has historically been demonstrated to have a very high degree of reliability. During the period from 1967 to 1978, Union Electric established multiple interconnections at 345-kV with neighboring power systems in Missouri, Illinois, Iowa, Kansas, Oklahoma and the TVA system. Grid availability was further strengthened by an additional 345/500-kV interconnection to the Middle South System in 1984. In view of the applied system design and based on past performance of the transmission system, uninterrupted transmission grid availability necessary to meet all requirements is projected over the life of the Callaway Unit.

8.3 ONSITE POWER SYSTEMS

8.3.1 AC POWER SYSTEMS

8.3.1.1 Description

This description relates only to the non-class 1E ac system exterior to the power block (site ac system), and the ac power feed to the emergency operations facility (EOF).

The site ac system is supplied by four feeders from two independent 13.8-kV switchgear groups in the Unit 1 power block and by one feeder from one of two 13.8-kV switchgear breakers for either Safeguard Transformers A or B in the 345-kV switchyard. Each switchgear group in the power block is sized to provide 21.7 MVA to the site ac system through two site feeder circuit breakers. The controls, protective relaying and metering for the four 13.8-kV site feeders are within the Unit 1 power block. Each of the two 13.8-kV switchgear breakers in the switchyard is sized to handle more than the maximum connected load on this feeder of 14.5 MVA, 4.1 MVA for the intake transformer and 10.4 MVA for the site power center transformers. These two breakers are interlocked such that only one can be closed at a time. The control, protective relaying, and metering for these two breakers are located locally on the 13.8-kV switchgear. These breakers cannot be operated from within the Unit 1 power block.

The site ac system is 13.8-kV, radial, resistance grounded neutral, with secondary selective capability with exceptions. Secondary selective capability is not provided where there is only a single circuit and transformer. The system is shown on Figure 8.3-1. Distribution near the power block is underground in concrete-encased PVC ducts. The river intake, approximately 5 miles from the power block, is supplied by two 13.8-kV overhead lines on separate wooden pole lines, with bare conductors and shield wire. These lines connect through disconnect switches to underground cables in PVC ducts at both the power block end and the river intake end.

The transformers, located adjacent to the loads, are outdoor, oil-filled three-phase, 60-Hz delta-primary, wye-secondary types with no-load tap changers.

The transformers serving the river intake, the circulating water pumps and the service water pumps are substation type, rated for normal operation at 55 degrees C rise and with nonreduced BIL rating (13.8-kV windings with 110-kV basic impulse rating).

The river intake pumps, electric boilers and load centers are normally served by two transformers, each serving a portion of the load. If one transformer or its 13.8-kV feeder should fail, the other transformer and feeder will serve the load of pumps, boilers, and load centers up to the 65 degree C rise fan-cooled rating of the transformer. Under single feeder/transformer operation in the winter and depending on overall requirements, it will be necessary to shift some loads between buses and to limit operation to only one of the two boilers at the intake in order to prevent overload (more than 21.7 MVA) on the bus in the power block or overload (more than 10.5-MVA) on the intake transformer.

The circulating water pumps and service water pumps are normally served by three transformers, each of which serves one circulating water and one service water pump. If one transformer or its 13.8-kV feeder should fail, one of the two remaining transformers and its associated feeder will serve two circulating water pumps and two service water pumps within the 65 degree C rise fan-cooled rating of the transformer. The 4160-V switchgear feeder and tie circuit breaker are interlocked to prevent any single transformer and its feeder from serving more than two circulating water pumps and two service water pumps.

Building and miscellaneous loads (such as the service building, switchyard, water treatment plant, fire protection, etc.) are served by power center type transformers which have primary load break disconnect switches and fuses. These transformers have various ratings, from 500 to 1500 KVA, for normal operation at 65 degrees C rise and with reduced BIL rating (13.8-kV windings with 95-kV basic impulse rating). The security building is served by two 480-V feeders from two separate buses on the 480-V load center in the service building. A security diesel generator is provided to supply 480-V backup power upon loss of the security building 480-V feeders. This generator also has adequate capacity to supply 480-V backup power to the blackout transfer switch in the switchyard to feed essential equipment upon loss of the switchyard 480-V power. The technical support center (TSC) is served by single 480-V feeder from one bus on the 480-V load center in the site switchgear building. An emergency diesel generator is provided in the TSC to supply 480-V backup power upon loss of the normal TSC 480-V feeder.

The secondard 4160-V and 480-V switchgear and motor control equipment are located near the served loads.

The 4.16-kV secondard circuit breakers located outside the power block, except the boiler feeder breakers at the intake, are controlled from the site related panel in the main control room.

Controls, instrumentation and indication for the major cooling water systems' pumps, valves, and equipment located on the plant site are provided in the main control room. The remote river intake pumphouse control and indication for the pumps, valves, and load centers are also provided in the main control room. The control for energizing the electric boilers at the intake is provided locally at the intake pump house.

The three-phase 480-V ac power feed to the EOF is supplied by a single pad-mounted distribution transformer with its primary connected to the Callaway Electric Cooperative (CECO) 12.47-KV overhead line in the area. The CECO line disconnect switch and fuse is connected via an underground cable to the transformer disconnect switch. Also, an emergency diesel generator is provided at the EOF to supply 480-V backup power.

8.3.2 DC POWER SYSTEMS

8.3.2.1 Description

This description relates only to the non-Class 1E 125-V dc system exterior to the power block (site dc system), and the 125-V dc system at the river intake pump house.

The site dc system is supplied by two 200-A dc feeders from two independent dc switchboards in the Unit 1 power block. Each feeder is connected to each major site building. At these buildings, a manual transfer switch is provided to select the normal or the emergency circuit to feed the local dc distribution panel in the building. For several other dc loads, only a single circuit from one of the distribution panels is provided.

The 125-V dc system at the river intake pump house consists of one 125-V dc battery, two load sharing battery substitute type battery chargers, and a distribution panel. Circuits from the panel provide the control power for the various river intake equipment.

8.4 ALTERNATE EMERGENCY POWER SYSTEM (AEPS)

8.4.1 DESCRIPTION

An alternate, non-safety related, emergency AC power system consisting of the 69-kV Central Electric Reform Substation and four 2-MW, 13.8-kV diesel generators is provided for supplying power to the plant Class 1E safety bus in the unlikely event of a loss of offsite power to the plant switchyard and concurrent inoperability of both safety-related emergency diesel generators. Power from the Central Electric Power Cooperative is supplied through a 69-kV/13.8-kV, 11.2-MVA/13.7-MVA, automatic load tap-changing, step-down transformer which feeds into 13.8-kV switchgear located at the substation. Alternatively, power from the four 2-MW diesel generators is fed directly into the 13.8-kV switchgear located at the substation.

From the substation switchgear, a 13.8-kV underground line runs to a 13.8-kV/4.16-kV, 12-MVA/16-MVA transformer located approximately 1.5 miles southeast of the substation. From there, an underground 4.16-kV line is connected to 4.16-kV switchgear located approximately 1100 feet south (plant north) and directly plant west of the control building. The 4.16-kV switchgear can provide power to either (or both) of the safety-related 4.16-kV NB buses as well as the non-safety auxiliary feedwater pump.

While being supplied with power via the substation 69-kV/13.8-kV transformer or with power being supplied by three of the four diesel generators, the AEPS is capable of supplying essential plant loads necessary to safely and reliably shut down the reactor and maintain it in a safe shutdown condition, as well as providing power to the 700-hp non-safety auxiliary feedwater pump.

To connect the AEPS to an NB bus, two in-series, normally open breakers are required to be closed. The first breaker is on the AEPS 4.16-kV bus and is operated via the Human-Machine Interface (touch screen controller) in the main control room or locally at panel PA50102. The second breaker is part of the NB switchgear and is operated via a hand switch on panel RL012 in the main control room.

The NB breakers supplying power from the AEPS utilize the undervoltage relay contacts from LSELS to trip on an undervoltage condition.

Despite the capability of the AEPS to provide power to the plant Class 1E buses in the unlikely event of a loss of offsite power and concurrent inoperability of both safety-related emergency diesel generators (NE01 and NE02), no credit is taken for the AEPS in the coping analysis required pursuant to 10 CFR 50.63 for a postulated station blackout (SBO).