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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES, FORT CALHOUN STATION

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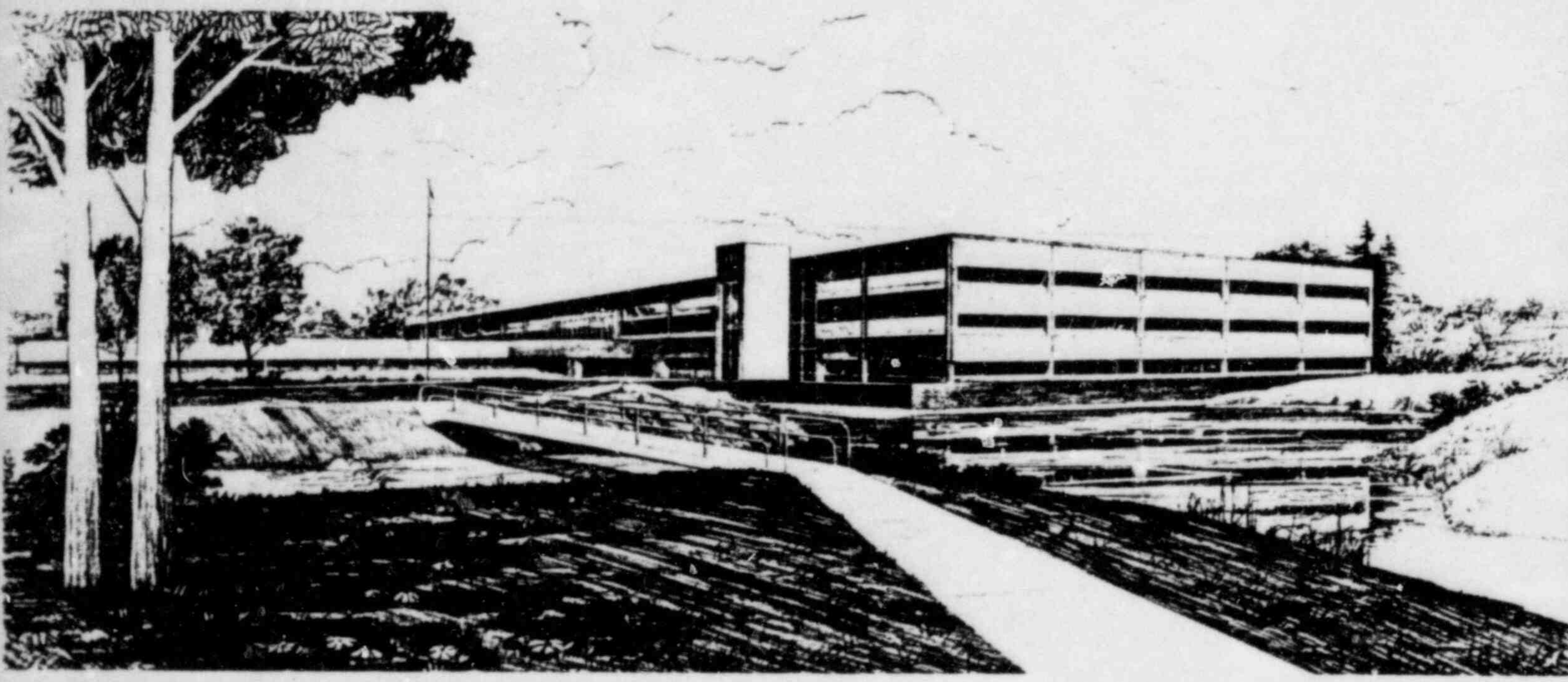

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EG&G Idaho

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FORT CALHOUN STATION

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ABSTRACT

This EG&G Idaho, Inc., report provides a review of the capacity and the capability of the onsite distribution system at the Fort Calhoun Station, in conjunction with the offsite power sources, to automatically start and continuously operate all required safety loads.

FOREWORD

This report is supplied as part of the Selected Operating Reactors Issues Program being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Licensing, by EG&G Idaho, Inc., NRC Licensing Support Section.

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FORT CALHOUN STATION

1. INTRODUCTION

An event at the Arkansas Nuclear One station on September 16, 1978, is described in NRC IE Information Notice No. 79-04. As a result of this event, station conformance to General Design Criterion (GDC) 17 is being questioned at all nuclear power stations. The NRC, in the generic letter of August 8, 1979, "Adequacy of Station Electric Distribution Systems Voltages," [1] required each licensee to confirm, by analysis, the adequacy of the voltage at the Class 1E loads. This letter included 13 specific guidelines to be followed in determining if the load terminal voltage is adequate to start and continuously operate the Class 1E loads.

In response to the generic letter and questions from the staff, the Omaha Public Power District, the licensee for the Fort Calhoun Station, submitted information and analyses on August 31, 1979,[2] March 20, 1980,[3] July 2, 1981,[4] August 31, 1981,[5] March 19, 1982,[6] May 21, 1982,[7] December 1, 1982,[8] and April 22, 1983.[9] Results of additional load flow studies were submitted on August 30, 1983.[10] Results of revised analyses were submitted on December 19, 1983,[11] and clarified on May 4, 1984.[12] These submittals, the Final Safety Analysis Report and submittals of July 29, 1977,[13] November 21, 1977,[14] July 12, 1978,[15] and August 28, 1978,[16] complete the information reviewed for this report.

Based on the information supplied by the Omaha Public Power District, this report addresses the capacity and capability of the onsite distribution system of the Fort Calhoun Station, in conjunction with the offsite power system, to maintain the voltage for the required Class 1E equipment within acceptable limits for the worst-case starting and load conditions.

2. DESIGN BASIS CRITERIA

The positions applied in determining the acceptability of the offsite voltage conditions in supplying power to the Class 1E equipment are derived from the following:

1. General Design Criterion 17 (GDC 17), Electric Power Systems, of Appendix A, General Design Criteria for Nuclear Power Plants, of 10 CFR 50.

2. General Design Criterion 13 (GDC 13), Instrumentation and Control, of Appendix A, General Design Criteria for Nuclear Power Plants, of 10 CFR 50.

3. IEEE Standard 308-1974, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

4. Staff positions as detailed in a letter sent to the licensee, dated August 8, 1979.[1]

5. ANSI C84.1-1977, Voltage Ratings for Electric Power Systems and Equipment (60 Hz).

Five review positions have been established from the NRC analysis guidelines[1] and the above listed documents. These positions are stated in Section 5.

3. SYSTEM DESCRIPTION

Figure 1 of this report is a simplified sketch of the Fort Calhoun electrical single-line diagram. Generator Auxiliary Transformers T1A-1 and T1A-2 are normally fed from the main generator. With the main generator disconnected (by a motor-operated disconnect switch), these transformers can also be backfed by the main transformer from the 345 kV grid. Station Auxiliary Transformers T1A-3 and T1A-4 are connected to the 161 kV grid. Any two of these four transformers are rated as capable of

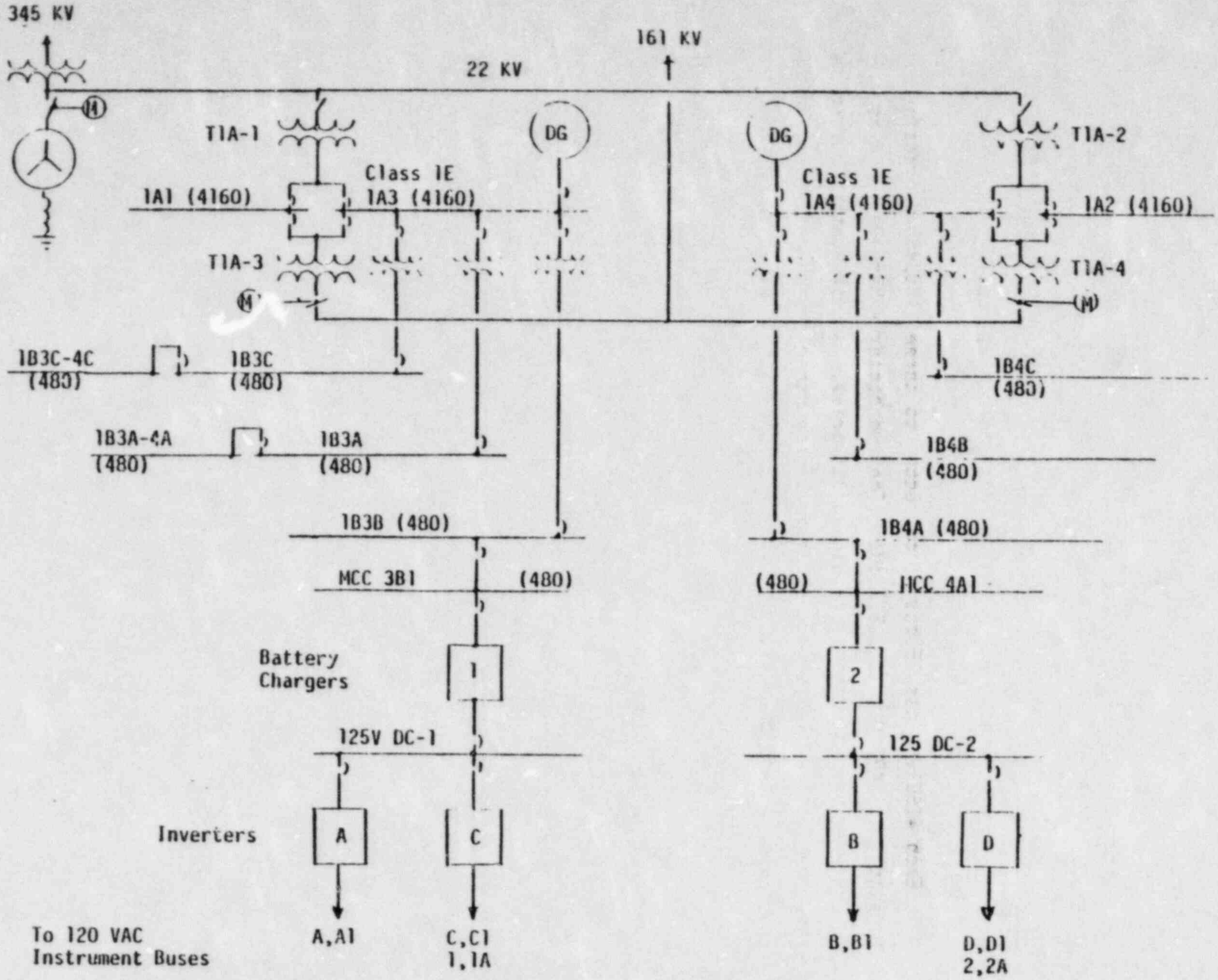

Figure 1. Fort Calhoun unit single-line diagram.

supplying the total unit auxiliary load. Automatic fast transfers are provided to switch the power source from the generator auxiliary transformers to the station auxiliary transformers.

Should offsite power fail, two emergency diesel generators are available. These are automatically started and loaded by the Class 1E distribution system. These diesels are each maintained in a warm standby condition and have independent air start and closed cooling water systems.

Each 4160 V Class 1E bus is connected to three 4160/480 V transformers to supply the 480 V Class 1E loads. The two battery chargers shown on Figure 1 supply the unit dc buses and batteries. A third battery charger, not shown, is available should either of the other two be out of service. The two dc buses power four inverter fed 120 V ac instrument buses.

4. ANALYSIS DESCRIPTION

4.1 Design Changes

The voltages shown on Table 1 are based on the licensee's change of the station auxiliary transformer taps to the 161 kV tap (from the 165 kV tap).[15] This change was completed in 1978.

4.2 Analysis Conditions

The Omaha Public Power District has determined by load flow analysis that the maximum 161 kV offsite grid voltage is 169 kV (359 kV for the 345 kV grid). The minimum expected 161 kV offsite grid voltage is 163 kV (347 kV has been measured on the 345 kV grid).

The licensee has analyzed the offsite source in conjunction with the onsite distribution system under extremes of load and offsite voltage conditions to determine the terminal voltages at typical Class 1E equipment. The worst-case Class 1E equipment terminal voltages occur under the following conditions:

TABLE 1. CLASS 1E EQUIPMENT VOLTAGE RATINGS AND ANALYZED WORST CASE LOAD TERMINAL VOLTAGES (% of nominal voltage)

		Maximum		Minimum		
					Analyzed	
Equipment	Condition	Rated	Analyzed	Rated	Steady State	Transient
4160 V Motors	Start	--	--	70	--	83.0[a]
	Operate	110	104.8	90	92.7	--
4000 V Motors	Start	--	--	70	--	86.3[a]
	Operate	110	109.0	90	96.4	--
460 V Motors	Start	--	--	70	--	b
	Operate	110	109.0	90	93.8	--
AC Starters	Pickup	--	--	85	--	b
	Dropout	--	--	72	--	b
	Operate	110	109.0	90	90.4	--

a. Bus voltage.

b. The licensee did not calculate this value as the degraded voltage protection relays on the Class 1E buses will operate to protect the equipment from less than adequate voltages.

1. The maximum voltage occurs under minimum load conditions when the 161 kV source is at its maximum expected value and supplying unit loads via the station auxiliary transformer.

2. The worst-case transient voltage occurs when the 161 kV grid is at its minimum expected value supplying the maximum plant loads via the station auxiliary transformer concurrent with the start of a reactor coolant pump.

3. The minimum steady-state voltage occurs when the 161 kV grid is at its minimum expected value and all Class 1E loads and unit auxiliary loads are running.

4.3 Analysis Result

Table 1 shows the projected worst-case Class 1E equipment voltages. Motor voltage requirements include 4160 V, 4000 V and 460 V. Control power is dc except for some of the smaller 460 V motors that use ac for control power.

As shown in Table 1, all Class 1E equipment will be operated within its rated continuous voltage limits. The licensee has submitted data that shows that the motors will start and operate their loads (pumps and fans) at the analyzed voltages. The minimum expected transient voltages are above the minimum motor rating for a transient (starting) condition.

4.4 Analysis Verification

The Omaha Public Power District performed voltage measurement tests as part of an undervoltage study on the Fort Calhoun Station electrical distribution system, including all Class 1E buses down to the 120/208 V level, during December 1977. This was before the NRC letter,[1] which permits previous testing to be utilized. The voltage measurement tests involved electrically loading the station distribution buses, including all Class 1E buses down to the 120/208 V level, to at least 30% of full load. Motor-starting transient voltages were measured for the existing grid and Class 1E buses down to the 480 V level. Steady-state and motor-starting voltage measurements were not recorded at the 120/208 V level because all critical safety-related electric motors at Fort Calhoun operate at 480 V or higher voltage level.

Based on the previous voltage analysis, bus 1B4B was determined to have the lowest analyzed voltage. Therefore, only transient voltage measurements on bus 1B4B were recorded. Two separate motor-starting tests were conducted with Class 1E motors to provide voltage data. This test data was then compared to the analytically derived voltages for bus 1B4B. The first test involved starting the 300 HP containment spray pump SI-3B. The second test involved the concurrent starting of two motors, containment spray pump SI-3C and ventilation air fan motor VA-7D, with combined power

requirements of 425 HP. Voltage values above the 480 V level were not analyzed as recording equipment measuring transient voltage changes on the distribution grid (161 kV) and bus 1A4 (4.16 kV) measured no detectable voltage drops when the motors were started.

The test was done before the NRC generic letter was issued, and before the tap change of the station auxiliary transformers was made. The NRC generic letter allows the use of prior testing. The tap change provides a constant change, not a load variable change. Therefore, the test applied by the licensee is applicable after the tap change.

Comparison of the test and the analytically derived voltages show the calculated voltages to be lower than the test voltages. Thus, the analysis is a very conservative model of the actual distribution system. The calculated voltage of 429 V for the motor-starting analysis of SI-3B was found to be lower than the measured test voltage of 446.2 V (3.6% lower on a 480 V base). The calculated voltage of 421 V for the concurrent motor-starting analysis of SI-3C and VA-7D was also found to be lower than the measured test voltage of 436.5 V (3.2% lower on a 480 V base). The licensee states that selected variable parameters (e.g., motor locked rotor current) used in the calculation of the analytically derived voltages were conservative and account for the differences.

5. EVALUATION

Five review positions have been established from the NRC analysis guidelines[1] and the documents listed in Section 2 of this report. Each review position is stated below followed by an evaluation of the licensee submittals. The evaluations are based on implementation of the technical specification change described in Section 4.1.

<u>Position 1</u>--With the minimum expected offsite grid voltage and maximum load condition, each offsite source and distribution system connection combination must be capable of starting and of continuously operating all Class 1E equipment within the equipment voltage ratings.

The licensee has shown, by analysis, that the offsite power sources, in conjunction with the onsite distribution system, nave sufficient capability and capacity for continuously operating all of the Class 1E loads within the equipment voltage ratings (Table 1 and Section 4.3).

<u>Position 2</u>--With the maximum expected offsite grid voltage and minimum load condition, each offsite source and distribution system connection combination must be capable of continuously operating the required Class 1E equipment without exceeding the equipment voltage ratings.

The licensee has shown, by analysis, that the voltage ratings of the Class 1E equipment will not be exceeded (Table 1).

<u>Position 3</u>--Loss of offsite power to any of the redundant Class 1E distribution systems, due to operation of voltage protection relays, must not occur when the offsite power source is within expected voltage limits.

As shown in Table 2, the degraded voltage relays can cause the Class 1E loads to transfer to onsite power. Manual action would then be required to restore the offsite source. This condition would occur with the minimum expected offsite grid voltage and the maximum post-accident station and safety loads concurrent with the start of a large non-Class 1E load (such as a reactor coolant pump or a feedwater pump). The licensee indicates that starting either of these pumps under this condition is highly improbable. We concur with the licensee that such an occurrence is highly improbable.

Should a degraded grid occur concurrent with an accident and maximum post-accident station and safety loads, and should one of these large non-Class 1E loads be started, the Class 1E loads would transfer to the onsite diesel-generators automatically. Therefore, there is no compromise in providing adequate core cooling. Based on the situation being highly improbable, and because adequate core-cooling is assured even if it did occur, we find that the licensee's capability in regard to this position is acceptable.

TABLE 2. COMPARISON OF ANALYZED VOLTAGES AND UNDERVOLTAGE RELAY SETPOINTS (% of nominal voltage)

Location/Relays	Minimum Analyzed[a]		Relay Setpoint	
	Voltage	Time	Voltage	Time to Trip
4160 V bus, non-accident (loss of voltage)				
Steady-State	92.7	continuous	77.3	17 sec
Transient Motor-Starting	83.0	15 sec[b]	72.0	8 sec
4160 V bus, accident signal (degraded voltage)				
Steady-State	92.7	continuous	90	5 sec
Transient Motor-Starting	83.0	15 sec[b]	90	5 sec

a. Licensee has determined by analysis the minimum bus voltages with the offsite grid at the minimum expected voltage and the worst-case plant and Class 1E loads.

b. This is the time needed for voltage recovery under accident conditions when starting a reactor coolant pump. The start of a feedwater pump under accident conditions also requires more than 5 seconds. The licensee states that the start of these pumps under accident conditions is highly improbable.

Position 4--The NRC letter[1] requires that test results verify the accuracy of the voltage analyses supplied.

The test results provided by the Omaha Public Power District show that the actual voltage is approximately 3.4% higher than the voltage shown in the analysis.

Position 5--No event or condition should result in the simultaneous or consequential loss of both required circuits from the offsite power network to the onsite distribution system (GDC 17).

The licensee has analyzed the onsite connections to the offsite power grid and determined that no potential exists for the simultaneous or the consequential loss of both circuits from the offsite grid.

6. CONCLUSIONS

The voltage analyses submitted by the Omaha Public Power District for the Fort Calhoun Station were evaluated in Section 5 of this report. It was found that:

1. Voltages within the operating limits of the Class 1E equipment are supplied for all projected combinations of plant load and offsite power grid conditions.

2. The test performed by the Omaha Public Power District verifies the accuracy of the analysis, and shows inherent conservatism.

3. The licensee has determined that no potential for either a simultaneous or a consequential loss of both offsite power sources exists.

4. Loss of offsite power to the Class 1E loads, due to operation of voltage protection relays, could occur with the offsite grid voltage within its expected limits when starting a large non-Class 1E load under accident conditions. We concur with the licensee that this is a highly improbable event, and therefore, the Fort Calhoun station is acceptable in this regard.

7. REFERENCES

1. NRC letter, William Gammill to All Power Reactor Licensees (Except Humboldt Bay), "Adequacy of Station Electric Distribution Systems Voltages," August 8, 1979.

2. Omaha Public Power District (OPPD) letter, W. C. Jones to W. Gammill, NRC, August 31, 1979.

3. OPPD letter, W. C. Jones to Director of Nuclear Reactor Regulation, NRC, March 20, 1980.

4. OPPD letter, W. C. Jones to R. A. Clark, NRC, July 2, 1981.

5. OPPD letter, W. C. Jones to R. A. Clark, NRC, August 31, 1981.

6. OPPD letter, H. B. Tucker to R. A. Clark, NRC, March 19, 1982, LIC-82-133.

7. OPPD letter, W. C. Jones to R. A. Clark, NRC, "Adequacy of the Fort Calhoun Station Electrical Distribution System Voltages," May 21, 1982, LIC-82-208.

8. OPPD letter, W. C. Jones to R. A. Clark, NRC, "Adequacy of the Fort Calhoun Station Electrical Distribution System Voltages," December 1, 1982, LIC-82-390.

9. OPPD letter, W. C. Jones to R. A. Clark, NRC, "Adequacy of the Fort Calhoun Station Electrical Distribution System Voltages," April 22, 1983, LIC-83-097.

10. OPPD letter, W. C. Jones to R. A. Clark, NRC, "Adequacy of the Fort Calhoun Station Electrical Distribution System Voltages," August 30, 1983, LIC-83-199.

11. OPPD letter, W. C. Jones to J. R. Miller, NRC, "Adequacy of Station Electric Distribution System Voltages at the Fort Calhoun Station, Unit No. 1," December 19, 1983, LIC-83-305.

12. OPPD letter, W. C. Jones to J. R. Miller, NRC, "Adequacy of Station Electric Distribution System Voltages at the Fort Calhoun Station, Unit No. 1," May 4, 1984, LIC-84-132.

13. OPPD letter, T. E. Short to Director of Nuclear Reactor Regulation, NRC, July 29, 1977.

14. OPPD letter, T. E. Short to Director of Nuclear Reactor Regulation, NRC, November 21, 1977.

15. OPPD letter, T. E. Short to Director of Nuclear Reactor Regulation, NRC, July 12, 1978.

16. OPPD letter, T. E. Short to R. W. Reid, NRC, "Application for Amendment of Operating Licensee," August 28, 1978.

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