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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES, NORTH ANNA POWER STATION, UNIT NOS. 1 AND 2

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U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory

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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

NORTH ANNA POWER STATION, UNIT NOS. 1 AND 2

July 1982

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Reliability and Statistics Branch
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EG&G Idaho, Inc.

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ABSTRACT

This EG&G Idaho, Inc., report reviews the capacity and the capability of the onsite power distribution system at the North Anna Power Station, in conjunction with the offsite power sources, to automatically start and continuously operate all required safety-related loads.

FOREWORD

This report is supplied as part of the "Selected Operating Reactors Issues Program (III)" being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Licensing, by EG&G Idaho, Inc., Reliability and Statistics Branch.

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NORTH ANNA POWER STATION, UNIT NOS. 1 AND 2

1.0 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 Criteria (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.

The Virginia Electric and Power Company (VEPCO), at the time of this generic letter, was submitting independently, for NRC review, analysis of the projected voltage conditions at the North Anna Power Station. These analyses, dated August 7, 1979, for Unit No. 2[2] and August 16, 1979, for Unit No. 1,[3] were tied to this review by the VEPCO response of October 9, 1979.[4] At the request of the NRC, VEPCO provided additional information for this review on August 20, 1980,[5] and on September 24, 1980.[6] Other correspondence and telephone conversations resulted in a schedule, submitted on August 21, 1981,[7] for the submittal of the remaining information germane to this review. This information was submitted to the NRC in letters of December 1, 1981,[8] and January 20, 1982,[9] with the bulk of the information provided and condensed in the VEPCO submittal of February 26, 1982.[10] Additional information was provided on May 20, 1982,[11] on June 4, 1982,[12] and on July 1, 1982.[13]

Based on the information supplied by VEPCO, this report addresses the capacity and capability of the onsite distribution system of the North Anna Power 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.

2.0 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), "Electrical Power Systems," of Appendix A, "General Design Criteria for Nuclear Power Plants," of 10 CFR 50.

2. General Design Criterion 5 (GDC 5), "Sharing of Structures, Systems, and Components," of Appendix A, "General Design Criteria for Nuclear Power Plants," of 10 CFR 50.

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

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

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

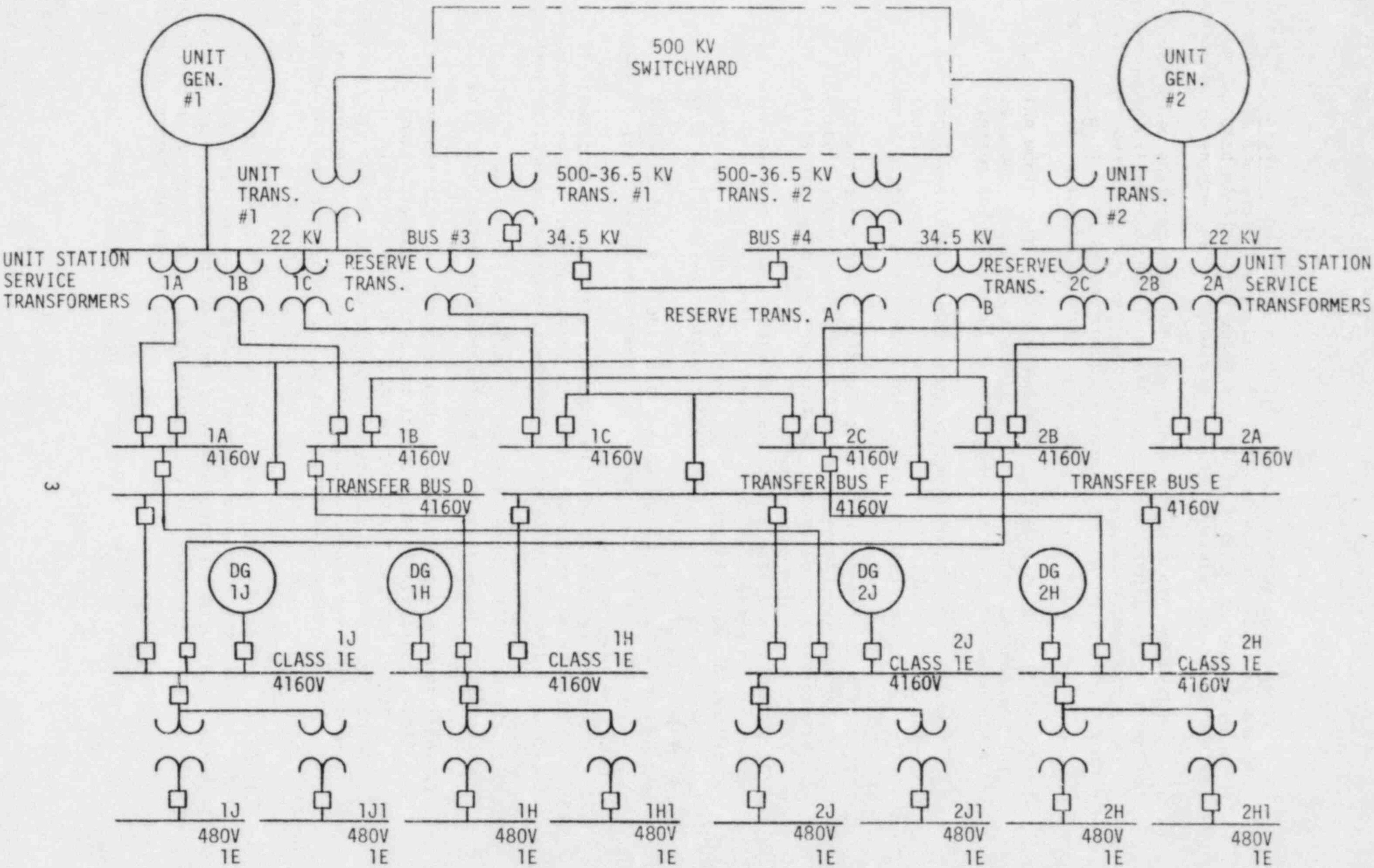
6. ANSI C84.1-1977, "Voltage Ratings for Electric Power Systems and Equipment (60 Hz)."

Six review positions have been established from the NRC analysis guidelines[1] and the above-listed documents. These positions are stated in Section 5.0.

3.0 SYSTEM DESCRIPTION

Figure 1 shows the electrical distribution system at the North Anna Power Station. Each unit has two 4160V Class 1E buses. These are designated 1J, 1H, 2J and 2H. Each of these buses provides 4160V power to high horsepower safety-related equipment and to two 4160V/480V transformers for safety-related equipment that requires less power. 480V Motor Control Center (MCC) loads have individual 460V/115V control power transformers. The breaker control circuits for the 4160V and the 480V buses are supplied power by the DC power distribution system, and thus are independent of this review. 115 VAC vital loads and instrumentation are supplied power from uninterruptable power supplies (DC backed). Should these power supplies fail, self-regulating transformers provide a stable (to within 2%) voltage.

With the completion of planned modifications (see Section 4.1), the 4160V Class 1E buses will be supplied power from the following sources: Bus 1J will normally be powered by reserve transformer A via transfer bus D. Alternately, a manually established connection to Unit 2 bus 2B is possible, with either the Unit 2 generator or reserve transformer B as its source. Bus 1H will normally be powered by reserve transformer C via transfer bus F. Alternately, a manually established connection to bus 1B is possible, with the Unit 1 main generator or main transformer being its preferred source. Bus 2J will also be normally powered by reserve transformer C via transfer bus F. Alternately, a manually established connection to bus 1A is possible, with the Unit 1 main generator or main transformer being its preferred source, or reserve transformer A as an alternate source. Bus 2H will be normally powered by reserve transformer B via transfer bus E. Alternately, a manually established connection to bus 2C is possible. This bus derives power from the Unit 2 generator, or reserve transformer C. Thus, it is possible, for buses 1H, 2J and 2H to be powered by reserve transformer C. VEPCO has proposed operating restrictions that prevent more than two of these buses being connected to this transformer simultaneously. There are no automatic transfers of these buses between offsite power sources.



NORTH ANNA
STATION ONE LINE DIAGRAM
FIGURE 1

4.0 ANALYSIS DESCRIPTION

4.1 Design/Operation Changes. The voltages shown on Table 1 are based on the following licensee proposed changes:

1. VEPCO, by analysis and by test, will attempt to rerate the motor operated valves (MOV) to assure operation at less than design voltage limits. Where this is not possible, VEPCO will replace the motors of the MOVs. This will be completed by the second refueling outage of each unit after September 1, 1982.

2. Load shedding when Unit 2 transfers to the reserve transformers simultaneously with a safety injection (SI) or Containment Depressurization Actuation (CDA)[a] in Unit 1.

3. Trip the 34.5kV switchyard reactors when either unit has a SI or CDA.

4. Install overvoltage alarms on all Class 1E buses.

5. Modify the Load Tap Changer (LTC) controls on the reserve transformers to eliminate response delays in the LTC for the first three minutes following either an SI or a CDA in either unit or on transfer of the unit loads to the reserve transformers.

6. Block the auto-start of large non-Class 1E motors when their power source is the same as an emergency bus of a unit with either an SI or CDA.

7. Elimination of the automatic transfer of the Class 1E buses from the reserve transformers to the Normal Station Service Buses.

8. Trip all circulating water pumps when a unit has an SI or CDA if Buses 16 and 26 (not shown in Figure 1) are supplied power from the same reserve transformer.

Additionally, VEPCO is implementing operating restrictions to:

1. Maintain the generator bus voltage above 21.7kV when a "J" bus is fed from a station service bus.

2. Limit the load on a station service bus when a "J" bus is fed from it.

3. Prevent powering bus 2H from reserve transformer C, when bus 2J is also powered by this source.

VEPCO has implemented a voltage schedule and procedures to ensure that the grid voltage is maintained between 505 and 535kV.[13]

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a. A CDA includes all motors started for an SI plus additional motors required for the CDA.

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

		Maximum		Minimum		
					Analyzed[a]	
Equipment	Condition	Rated	Analyzed[b]	Rated	Steady State	Transient
4000V Motors	Start	--	--	70	--	82.5
	Operate	110	114.3	90	96.3	--
460V Motors	Start	--	--	70	--	67.9
	Operate	110	117.6	90	91.4	--
460V MOV	Start	--	--	c	--	68.1
	Operate	110	117.6	90	d	--
MCC Starters	Pickup	--	--	75	--	65.1
	Dropout	--	--	60	--	65.1
	Operate	110	127	90	91.5	--

a. VEPCO supplied bus voltage minus the average feeder voltage drop. The average feeder voltage drops were: 4160V steady state-0.4%; transient-1.2%; 460V steady state-3.3%; transient-5.0%.

b. VEPCO is installing an overvoltage alarm on each Class 1E bus. Each will be set at 110% of the nominal load voltage. This will enable station personnel to take action to reduce the voltage available to the equipment.

c. VEPCO is presently rerating MOVs replacing motor operators as needed so that all MOVs will start at 80, 84 or 86%. VEPCO indicates that with these ratings, all MOVs will operate within 4 seconds of an initial accident, and that this ensures proper actuation of the valves.

d. Considered as a transient case only. The MOV operation will be complete in less than 3.0 seconds. In that case, the steady state voltage would be approximately 91.4%.

4.2 Analysis Conditions. VEPCO has determined by contingency planning that the maximum expected offsite grid voltage is 535kV and the minimum expected offsite grid voltage is 505kV. VEPCO is implementing procedures to ensure the grid voltage will not deviate from these limits.

VEPCO has analyzed each offsite source to the onsite distribution system under extremes of load and offsite voltage conditions to determine the voltages available to the Class 1E equipment. With the corrective actions of Section 4.1 taken, the following conditions resulted in the worst Class 1E equipment terminal voltages:

1. The worst case steady state 4160V voltages occur to buses powered by a unit auxiliary transformer when the offsite grid voltage is minimum and with a CDA in Unit 2 and Unit 1 generating at 21.5kV.

   The lowest 480V steady state voltages occur when power is supplied by unit auxiliary transformers of Unit 1, the offsite grid voltage is minimum, Unit 2 has a CDA and Unit 1 is tripped.

2. The worst transient voltages occur with the minimum offsite grid voltage and with a CDA in Unit 1 concurrently with Unit 2 transferring to the reserve transformers for a power source.

3. The maximum steady state voltage occurs with the maximum offsite grid voltage and with no station loads or transformer or feeder cable losses, while backfeeding through the normal buses via the unit station service transformers.

4.3 Analysis Result. Table 1 shows the projected worst case voltages available to the Class 1E equipment.

It shows that steady state voltages will be maintained above the minimum required for any operating condition, and that the minimum transient voltage at the 4000V loads will not cause these motors to stall.

It also shows the potential to stall 460V loads. VEPCO indicates that all MOVs will be actuated and operating within an acceptable 4 second period, and that other 460V loads, in particular the quench spray pump, will start accelerating within 2 seconds as the voltage recovers (the 4kV motors are completely accelerated and the voltage is stablized within 4 seconds). This is acceptable. Some of the motor control center contactors may not be able to pickup to operate additional loads during this transient period. The loads will pickup within a few (less than 4) seconds as the voltage recovers. No contactors will drop out during this period.

Table 1 also shows that for the no station load condition, the equipment voltage limits can be exceeded. Minimum station loads (lights, battery chargers, pumps and so forth) will reduce this potential. VEPCO is installing an overvoltage alarm on each Class 1E AC bus to allow operator action to correct the condition.

4.4 Analysis Verification. The computer analysis was verified[10] by recording the grid voltage, the position of the load tap changers and the voltages and currents of the 4160V and the 480V buses. This was done while the Unit 2 loads were transferred from the unit station service transformers to the reserve transformers and the subsequent start of a charging pump. An analysis was then done using the recorded grid and load and load tap changer data, and the results compared with the measured bus voltages.

The comparison shows that the Class 1E bus calculated voltages are within 2.1% of the measured voltage for the steady state condition and within 3.1% of the measured voltage for the transient condition. These errors were generally in the conservative direction. This close correlation shows that the assumptions used in the voltage analysis give an accurate representation of actual station voltages.

5.0 EVALUATION

Six review positions have been established from the NRC analysis guidelines[1] and the documents listed in Section 2.0 of this report. Each review position is stated below followed by an evaluation of the licensee submittals. The evaluations are based on completion of changes described in Section 4.1.

Position 1--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.

VEPCO has shown, by analysis, that the North Anna Power Station has sufficient capability and capacity for starting and continuously operating the Class 1E loads within the equipment voltage ratings (Table 1 and Section 4.3).

Position 2--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.

VEPCO has shown, by analysis, that the voltage ratings of the Class 1E equipment could be exceeded if no station load exists. VEPCO is installing an overvoltage alarm on each Class 1E AC bus (4160V & 480V) to allow operator action to reduce the potential overvoltage.[10]

Position 3--Loss of offsite power to either 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, voltage relays will not cause loss of Class 1E distribution systems when the offsite grid voltage is within expected voltage limits.

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

Location/Relays	Minimum Analyzed[a] Voltage	Minimum Analyzed[a] Time	Relay Setpoint Voltage (Tolerance)	Relay Setpoint Time
Unit 1 4160V bus				
Degraded grid	94.0	continuous	90% ($\pm$1.4V)	5 (56)[b] sec.
Loss of grid	80.6	4.2 sec.	71%	2 sec.
Unit 2 4160V bus				
Degraded grid	93.0	continuous	90% ($\pm$1.4V)	7 (60)[b] sec.
Loss of grid	80.5	6.5 sec.	71%	2 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. The first time is for an SI or CDA condition. The second time is for non-accident conditions.

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

VEPCO has supplied the required information which shows the analysis to be an accurate representation of the worst case voltage conditions for the Class 1E buses and loads.

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).

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

As a result of this analysis, VEPCO will maintain the 34.5kV tie breaker open, with two manual disconnects also open between the two 34.5kV buses, and the automatic close feature of the breaker removed. The power cable routing from the switchyard service transformers was also changed to eliminate a potential for a common cause failure of both offsite sources.

Position 6--As required by GDC 5, each offsite source shared between units in a multi-unit station must be capable of supplying adequate starting and operating voltage for all required Class 1E loads with an accident in one unit and an orderly shutdown and cooldown in the remaining units.

The North Anna Power Station is the site of two nuclear units. The units are not independently connected to the offsite power sources and have electrical power interconnections between units that are restricted by technical specification and operating procedures. VEPCO has shown that the shared offsite sources will be capable of supplying adequate starting and operating voltages for all required Class 1E loads with an accident in one unit and an orderly shutdown and cooldown of the other unit.

6.0 CONCLUSIONS

The voltage analyses submitted by VEPCO for the North Anna Power Station were evaluated in Section 5.0 of this report. Upon the completion of changes described in Section 4.1, 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 normal offsite power grid conditions, including an accident in one unit and the safe shutdown of the other unit. However, operator action is required should an overvoltage condition occur.

2. The test used to verify the analysis shows the analyses to be an accurate representation of the worst case conditions analyzed.

3. VEPCO has determined that no potential for either a simultanous or consequential loss of both offsite power sources exists.

4. Loss of offsite power to Class 1E buses, due to spurious operation of voltage protection relays, will not occur with the offsite grid voltage within its expected limits.

7.0 REFERENCES

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

2. VEPCO letter, S. C. Brown to J. P. O'Reilly, NRC Region II, August 7, 1979, Serial No. 403A.

3. VEPCO letter, C. M. Stallings to H. R. Denton, NRC, "North Anna Unit No. 1, Station Electrical Distribution System Voltages," August 16, 1979, Serial No. 352A.

4. VEPCO letter, C. M. Stallings to H. R. Denton, NRC, "Adequacy of Station Electric Distribution System Voltages," October 9, 1979, Serial No. 673/080879.

5. VEPCO letter, B. R. Sylvia to H. R. Denton, NRC, "Request for Additional Information, Electrical Distribution System Voltages," August 20, 1980, Serial No. 725.

6. VEPCO letter, B. R. Sylvia to H. R. Denton, NRC, "Request for Additional Information, Electrical Distribution System Voltages," September 24, 1980, Serial No. 725A.

7. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "Completion Schedule, General Design Criteria 17 Analysis," August 21, 1981, Serial No. 908A.

8. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "General Design Criteria 17 Analysis," December 1, 1981, Serial No. 908B.

9. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "General Design Criteria 17 Analysis," January 20, 1982, Serial No. 017.

10. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "General Design Criteria 17 Analysis," February 26, 1982, Serial No. 076.

11. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "General Design Criteria 17 Analysis," May 20, 1982, Serial No. 233.

12. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "General Design Criteria 17 Analysis," June 4, 1982, Serial No. 316.

13. VEPCO letter, R. H. Leasburg to H. R. Denton, NRC, "General Design Criteria 17 Analysis," July 1, 1982, Serial No. 374.