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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM
VOLTAGES, BEAVER VALLEY POWER STATION, UNIT NO. 1

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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES
BEAVER VALLEY POWER STATION, UNIT NO. 1

April 1982

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ABSTRACT

This EG&G Idaho, Inc. report reviews the capacity and the capability of the onsite distribution system at the Beaver Valley Power 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 Operating Reactors, by EG&G Idaho, Inc., Reliability and Statistics Branch.

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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

BEAVER VALLEY POWER STATION, UNIT NO. 1

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 to the Class 1E loads. This letter included 13 specific guidelines to be followed in determining if the voltage is adequate to start and continuously operate the Class 1E loads.

Duquesne Light (DL) responded to the NRC letter¹ with letters of October 15, 1979,² and February 22, 1980.³ The Final Safety Analysis Report (FSAR), additional analyses submitted on June 17, 1980,⁴ and a telephone call on July 11, 1980,⁵ provided information for this report. DL documented this telephone call on July 24, 1980.⁶ A letter of November 11, 1976,⁷ also provided information for the preparation of this report. Letters of December 15, 1981,⁸ and March 11, 1982,⁹ provide further information and analyses regarding the installation of automatic load tap changers on the station service transformers. A telephone conversation on April 7, 1982,¹⁰ clarified portions of these last two submittals.

Based on the information supplied by DL, this report addresses the capacity and capability of the onsite distribution system of the Beaver Valley Power Station, in conjunction with the offsite power system, to maintain the voltage within acceptable limits for required Class 1E equipment for the worst-case starting and load conditions. Unit 2 is not an operating reactor, therefore this report covers only the Unit 1 distribution system.

2.0 DESIGN BASIS CRITERIA

The positions applied in determining the acceptability of the offsite voltage conditions in supplying power to 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 guidelines¹ and the above-listed documents. These positions are stated in Section 5.

3.0 SYSTEM DESCRIPTION

Figure 1 of this report is a unit one-line diagram of the power sources and the Class 1E distribution system taken from Figure 8.1-1 of the FSAR. Class 1E 4160V buses 1AE and 1DF are supplied power from auxiliary buses 1A and 1D, respectively. When the unit generator is operating, these buses are powered by independent unit transformers. On a unit generator trip, these buses are automatically and independently connected via separate system auxiliary transformers 1A and 1B to the 138kV switchyard. The unit generator cannot be isolated from the unit transformers; therefore, the main transformer cannot supply offsite power to the Class 1E buses from the 345kV switchyard.

Each 4160V Class 1E bus supplies power to two 480V Class 1E buses via separate 4160V/480V transformers. 120V vital buses are normally supplied power from uninterruptable power supplies (UPS), however, when a UPS is undergoing maintenance, separate 480V/120V transformers supply power to the 120V vital buses. Other 120V buses that supply instruments and control systems as required by GDC 13 are powered by 480/240/120V transformers.

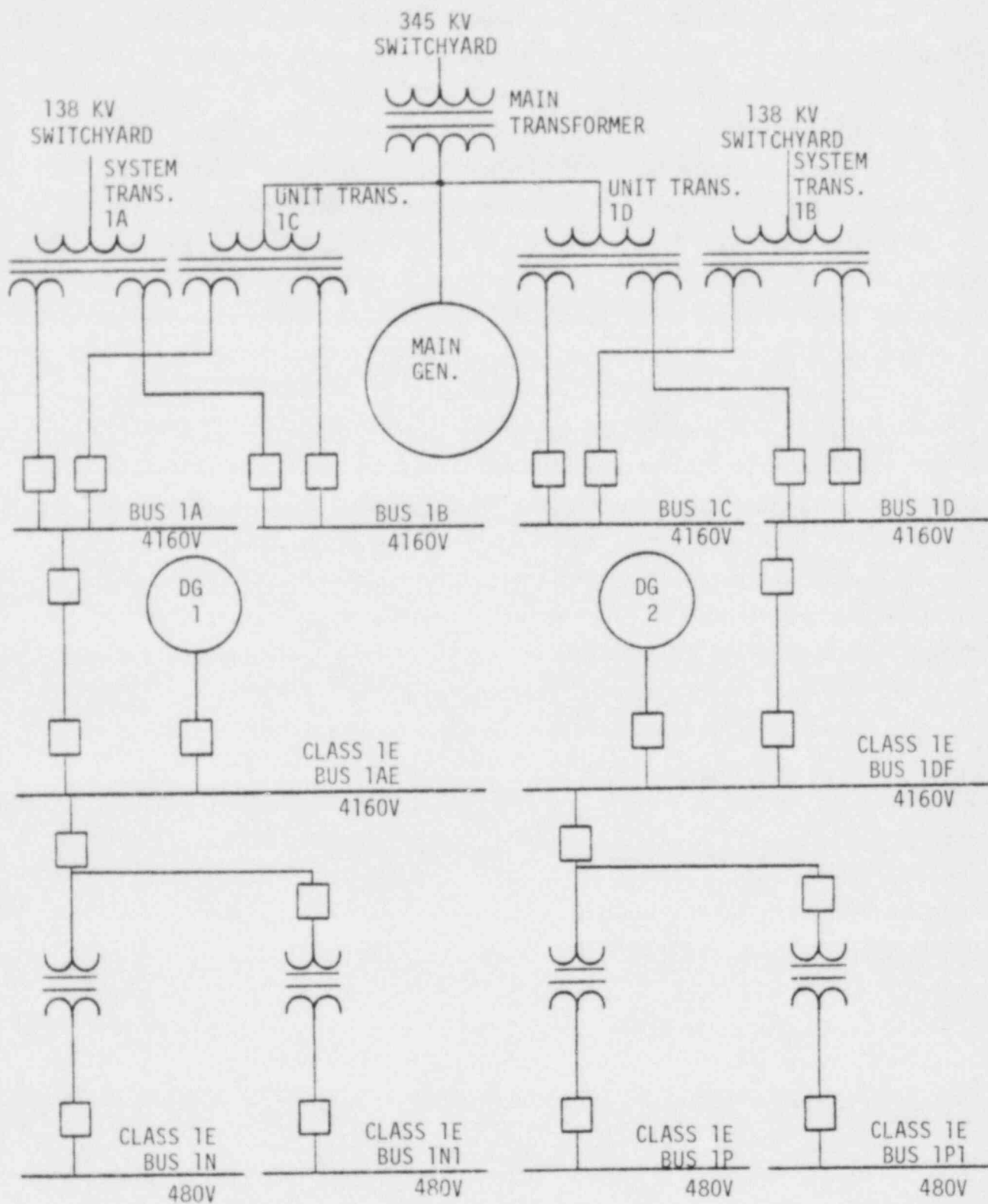
There are two Class 1E undervoltage relays on each 4160V Class 1E bus.^{2,6} The relays separate the Class 1E bus from offsite power should there be degradation of offsite power. There are also Class 1E undervoltage relays on 480V buses 1N and 1P that operate the same as the 4160V relays. Loss of voltage relays are on these same buses.

The FSAR indicates that control power for the Class 1E 4160V and 480V switchgear is 125V DC. 480V MCCs use AC control power.⁷

DL supplied the equipment operating ranges identified in Table 1.

4.0 ANALYSIS DESCRIPTION

4.1 Design Changes. DL submitted analyses^{3,4} based on the following proposed changes:



UNIT ONE LINE DIAGRAM
BEAVER VALLEY STATION
FIGURE 1

1. DL will install new station service transformers that have automatic tap changing capability.⁸ The tap changers can also be manually set from the control room.
2. The taps on the 480/240/120V transformers will be changed to give a 2-1/2% voltage boost.⁴
3. The transformers that supply backup power to the vital buses are being replaced with self-regulating transformers which will maintain the bus voltage within the required limits.⁴

The discussion in the text and the values in Table 1 of this report reflect that these modifications have been completed.

4.2 Analysis Conditions. DL has determined by load-flow studies that the maximum 138kV switchyard voltage is 143.4kV² and that the minimum is 133.7kV.⁹ DL has shown that the automatic load tap changers of the station service transformers can maintain the output of each transformer at 4360V \pm 52v, through all expected variations of the grid voltage.

DL has analyzed each offsite source to the onsite distribution system under extremes of load and offsite voltage conditions to determine the bus voltages available to the Class 1E equipment. The worst case Class 1E equipment terminal voltages occur under the following conditions:

1. The maximum analyzed load terminal voltages occur when the grid is maximum, each system auxiliary transformer is supplying power for its Class 1E buses, and no unit loads exist.
2. The minimum analyzed continuous load terminal voltages occur when the grid is minimum and each system auxiliary transformer is supplying the maximum connected auxiliary and Class 1E loads.

3. The minimum analyzed transient load terminal voltages occur under the same conditions as 2, concurrent with the start of a 6000 hp reactor coolant pump. The voltage is fully recovered within the 30 second deadtime of the automatic load tap changers.

4.3 Analysis Results. Table 1 shows the projected worst case Class 1E equipment terminal voltage.

A review of Table 1 shows that, with the exception of the transient condition on the 120V contactors, all the Class 1E loads are within the equipment rated voltages. This worst case transient condition will last less than 22 seconds³ before normal operating voltages (i.e., greater than 90%) are restored.⁴ Contactor pickup for the 480V MCC loads is prevented until the voltage recovers above 80%. It will not cause contactor dropout or spurious shedding of any loads.

4.4 Analysis Verification. The computer analysis was verified⁹ by measuring the grid and bus voltages, and the actual load of the buses and selected equipment while the unit was being restarted from shutdown.⁵ An analysis to determine bus voltages was completed using the measured offsite source voltage. The accuracy of the DL analysis is verified by comparing the results with the measured bus voltages.

Comparison of the measured and the analyzed voltages shows that the difference between the two voltage values is less than 0.66% for any Class 1E bus, including the steady state condition and the start of a reactor coolant pump.

5.0 EVALUATION

Six review positions have been established from the NRC analysis guidelines¹ and the documents listed in Section 2.0. Each review position is stated below, followed by the evaluation of the licensee submittals.

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

Equipment	Nominal Voltage (100%)	Maximum		Minimum		
		Rated	Analyzed	Rated	Analyzed	
					Steady state	Transient
4160V Motors						
Start	4160V	--	--	80 ^a	--	82.5
Operate		110	106.1	90	103.5 ^b	--
460V Motors						
Start	460V	--	--	80 ^a	--	80.7
Operate		110	108.1	90	98.4 ^b	--
120V MCC Starters						
Pickup	120V	--	--	80	--	77.3
Dropout		--	--	55	--	77.3
Continuous		110	103.5	80	94.3	--
Other Equipment ^c	120V Instruments and Controls					

a. DL states⁶ that they, "do not have documentation that all motors will start at 80% voltage, but by experience, we believe they will." 80% is conservative for the ratings of similar equipment in other nuclear stations.

b. Bus voltage has adequate margin to allow for feeder cable voltage drop.

c. The 120V vital buses are normally supplied power by inverters. Should an inverter be out of service, self-regulating transformers are used to maintain the vital bus voltage within $\pm 2\%$ for a $\pm 10\%$ change on the input voltage.⁶

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 rated equipment voltages.

DL has shown that, with the modifications of Section 4.1 completed, the Beaver Valley Power Station, Unit 1, has sufficient capacity and capability for starting and continuously operating the Class 1E equipment. While the Class 1E 480V contactors can have transient voltages below the contactor pickup rating, this should not be a problem, as the Class 1E motors are running when this transient voltage occurs and the contactor dropout voltage rating is not exceeded.

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 all Class 1E equipment without exceeding the rated equipment voltage.

DL has shown that, with the grid voltage at the maximum expected value and no unit loads, the voltage ratings of the Class 1E equipment are not exceeded.

Position 3--Loss of offsite power to either the redundant Class 1E distribution systems or the individual Class 1E loads, due to operation of voltage protection relays, must not occur when the offsite power source is within analyzed voltage limits.

As shown in Table 2, the voltage protection relays will not separate the Class 1E buses from the offsite power source during the analyzed starting transients or during maximum steady state load conditions.

Position 4--Test results should verify the accuracy of the voltage analyses supplied.

DL has shown the calculations to be an accurate representation of actual conditions of the Class 1E buses and loads.

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

Location Action	Minimum Analyzed		Relay Setpoint	
	Voltage ^a	Time	Voltage (Tolerance)	Time
4160V bus				
Degraded	103.5	continuous	90 (+3)	90 sec
Loss	82.5	22 sec	75	1 sec
480V bus				
Degraded	94.3	continuous	90 (+3)	90 sec
Loss	77.3	22 sec	75	41 sec

a. DL submitted voltages.

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).

DL has analyzed the Beaver Valley, Unit 1 connections to the offsite power grid and determined that no potential exists for either a simultaneous or consequential loss of both circuits to the offsite grid.⁴

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 Beaver Valley Power Station is presently a single unit station, therefore, this position does not apply.

6.0 CONCLUSIONS

The voltage analyses submitted by DL for Unit 1 of the Beaver Valley Power Station were evaluated in Section 5.0 of this report. It was found that, upon the completion of the changes described in Section 4.1:

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 used to verify the analysis accuracy shows the analyses to be an accurate representation of the worst case conditions analyzed.
3. DL 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 buses, due to spurious operation of the 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 Voltages," August 8, 1979.
2. DL letter, C. N. Dunn to Director of Nuclear Reactor Regulation, NRC, "Response to Requests for Information on Station Service Bus Voltages", October 15, 1979.
3. DL letter, C. N. Dunn to Director of Nuclear Reactor Regulation, NRC, "Station Service Bus Voltage Study", February 22, 1980.
4. DL letter, C. N. Dunn to Director of Nuclear Reactor Regulation, NRC, "Adequacy of Station Electric Distribution System Voltages," June 17, 1980.
5. Telecon, Ray Burski, DL, Tom Mayers, DL and Alan Udy, EG&G Idaho, Inc., July 11, 1980, at 4 p.m. EDT.
6. DL letter, C. N. Dunn, to Director of Nuclear Reactor Regulation, NRC, "Station Service Busses Undervoltage Relays," July 24, 1980.
7. DL letter, C. N. Dunn, to R. W. Reid, U.S. NRC, "Operation Under Degraded Voltage," November 11, 1976.
8. DL letter, J. J. Carey to Director of Nuclear Reactor Regulation, NRC, "Emergency Bus Transient Voltage Regulation", December 15, 1981.

9. DL letter, J. J. Carey to Director of Nuclear Reactor Regulation, NRC, "Emergency Bus Transient Voltage Regulation", March 11, 1982.
10. Telecon, Tom Mayers, DL and Alan Udy, EG&G Idaho, Inc., April 7, 1982.