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# ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES, FORT ST. VRAIN NUCLEAR GENERATING STATION

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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

# FORT ST. VRAIN NUCLEAR GENERATING STATION

July 1982

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Reliability and Statistics Branch
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EG&G Idaho, Inc.

TAC No. 46503
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## ABSTRACT

This EG&G Idaho, Inc., report reviews the capacity and the capability of the onsite distribution system at the Fort St. Vrain 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 (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.


The U.S. Nuclear Regulatory Commission funded the work under the authorization, B&R 20 19 10 11.

CONTENTS



FIGURE



TABLE

# ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

## FORT ST. VRAIN NUCLEAR GENERATING STATION

## 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 a letter of August 25, 1980, "Adequacy of Station Electric Distribution Systems Voltages,"[1] required the Public Service Company of Colorado (PSC) 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.

PSC responded with a letter of October 24, 1980.[2] They provided additional information in a letter dated March 19, 1981,[3] in a telephone conversation of March 27, 1981,[4] and in letters dated April 7, 1981,[5] and July 6, 1981.[6] The analyses contained in these submittals were replaced by submittals dated May 28, 1982,[7] and June 7, 1982.[8] These were discussed in telephone conversations in June 1982[9].

Based on the information supplied by the licensee, this report addresses the capacity and capability of the onsite distribution system of the Fort St. Vrain 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 is a simplified sketch of the unit single-line diagram of the Fort St. Vrain electrical distribution system. It shows that the 480V Class 1E buses 1, 2 and 3 are supplied power by independent transformers from 4160V buses 1, 2 and 3 respectively. These three buses are interconnected to a single reserve auxiliary transformer (RAT) which is the preferred source of offsite power. The alternate source of offsite power is via the unit auxiliary transformer, with the unit generator links removed.

120V Class 1E buses 1A and 1B are normally supplied power by DC bus powered inverters. Should an inverter be out of service, a connection to 120V bus 3 is available as an alternate source.

The licensee supplied the equipment operating ranges identified in Table 1.[7]

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

| | | Maximum | | Minimum | | |
|---|---|---|---|---|---|---|
| | | | | | Analyzed | |
| Equipment | Condition | Rated | Analyzed | Rated | Steady State | Transient |
| 460V Motors & Battery Chargers | Start | -- | -- | 85 | -- | 78.8 |
| | Operate | 110 | 110.5 | 90 | 91.2 | -- |
| 480V Starters | Pickup | -- | -- | 90 | -- | 79.1 |
| | Dropout | -- | -- | 55.4 | -- | 79.1 |
| | Operate | 114.6 | 106.0 | 91.7 | 93.7 | -- |
| Other Equipment[b] | | | | | | |

a. Established by test.[9]

b. 120V AC instrument buses are normally supplied power by DC powered inverters. Use of the alternate source is limited to 24 hours for one bus by technical specification LCO 4.6.1.

Notes:

1. Circuit breakers shown aligned for offsite power source.

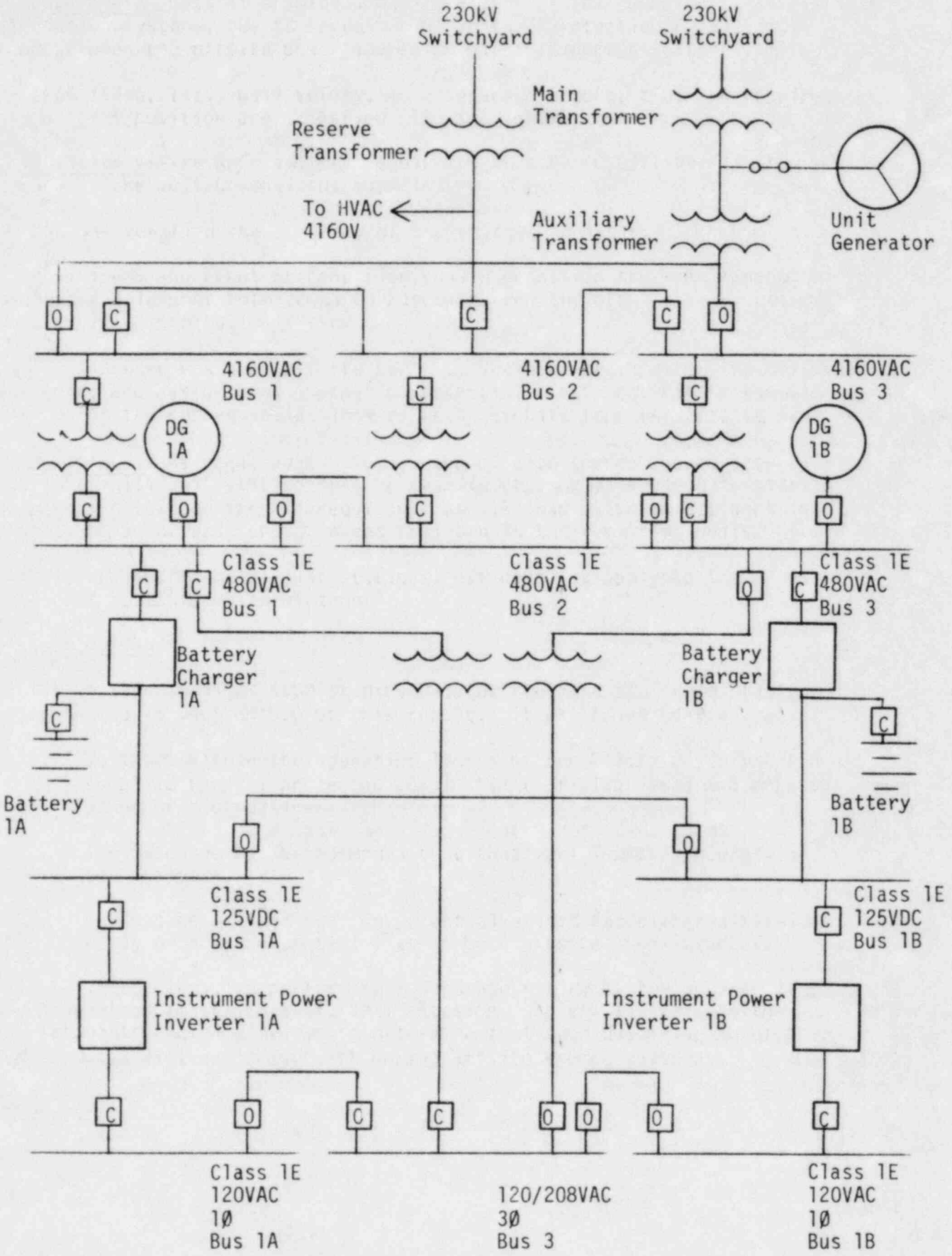


Figure 1. Fort St. Vrain unit single line diagram.

## 4.0 ANALYSIS DESCRIPTION

4.1 System Modifications. The licensee had plans, before the NRC letter[1] was issued, to improve their 480V Class 1E switchgear. Included in this modification are the installation of new 4160/480V transformers that have larger capacity and the replacement of the existing bus sections with new bus sections, also of larger capacity. The modifications will be accomplished with the third refueling outage for two of the buses and the fourth refueling outage for the other. The analysis supplied by the licensee[8] takes the characteristics and the capacities of the replacement distribution equipment into account.

4.2 Analysis Conditions. PSC has determined by past historical data that the maximum expected offsite grid voltage is 244kV and the minimum is 226kV.[8]

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

1. The worst loading condition occurs when all the loads that operate for a unit startup (unit trip loading is essentially the same) are carried by the reserve auxiliary transformer.

2. The worst transient voltage occurs on the Class 1E system under the above condition when starting the 4500 hp non-Class 1E boiler feedpump 1B on 4160V bus 2.

3. The highest steady state voltage was determined to occur with a unit shutdown load of ~6 megawatts being supplied by the reserve auxiliary transformer.

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

The analysis shows that with a worst-case combination of maximum system voltage and minimum shutdown loads, the 460V motors and battery chargers could be subject to voltages slightly in excess (~2V higher) of their maximum ratings. The licensee has determined that this equipment could function at this level without damage.[9]

The analysis shows that the minimum transient voltage can result in load terminal voltages that are less than rated. For the DC system, the battery would supply the load during the period of the transient should the charger not be able to supply power. No damage would occur and the charger would again supply the load within five seconds. All 460V Class 1E motors at the Fort St. Vrain station are built with a service factor of 1.15. This allows them to operate, without damage, during temporary overloads such as this. The licensee has verified by use of load and motor speed-torque curves that the motors will not stall during these worst-case analyzed

conditions. During this transient, a Class 1E AC powered contactor may not be able to pick up and start additional loads. However, the analysis shows that no running loads will drop out and that the voltage will recover within a few seconds to allow the contractor pickup.

4.4 Analysis Verification. The computer analysis was verified[7] by measuring the voltage at the grid, at the 4160V and 480V buses and at the terminals of the 150 hp fire pump motor, the largest Class 1E motor on 480V Class 1E bus 1. This was done with the unit operating, with the normally energized Class 1E loads operating. The voltages were measured for 5 conditions--before and during the start of the non-Class 1E 4500 hp boiler feed pump, before and during the start of the fire pump and with both of these pumps operating. Analyses, to determine the same bus and motor voltages under the same load conditions, were completed using the measured grid voltage and the recorded loads. The accuracy of the licensee's analysis is verified by comparing the results of the analysis with the measured voltages.

Comparison of the measured and the analyzed voltages shows that the difference between the two values is less than 1.1% for the bus voltages and less than 0.23% for the motor terminal voltage for a steady state condition; less than 0.92% for the bus voltages and less than 1.48% for the motor terminal voltage when starting either load. In all cases, the measured voltage was higher than the analyzed voltage, showing the conservatism of the computer analysis.

## 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.

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.

PSC has shown, by analysis, that the Fort St. Vrain 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.

PSC has shown, by analysis, that the voltage ratings of the Class 1E equipment could be slightly exceeded. If this occurs, no equipment damage is expected.

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.

EG&G Idaho, Inc., will verify, in a separate report, that the requirements of this position are satisfied (TAC No. 46504).

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

PSC has verified the accuracy of the voltage 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 Fort St. Vrain 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.

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.

This applies to multi-unit stations. It does not apply to the single-unit Fort St. Vrain station.

## 6.0 CONCLUSIONS

The voltage analyses submitted by PSC for the Fort St. Vrain station were evaluated in Section 5.0 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 licensee has performed a test that verifies the accuracy of the analysis.

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

EG&G Idaho, Inc., is performing a separate review of the undervoltage relay protection at the Fort St. Vrain station. This will evaluate the relay setpoints and time delays to determine that spurious tripping of the Class 1E buses will not occur with normal offsite source voltages.

## 7.0 REFERENCES


1. NRC letter, R. L. Tedesco, to P.S.C. (Warenbourg), "Adequacy of Station Electric Distribution Systems Voltage," August 25, 1980.

2. PSC letter, F. E. Swart to R. L. Tedesco, NRC, "Emergency Power Systems," October 24, 1980, P-80373.

3. PSC letter, F. E. Swart to A. Udy, EG&G Idaho, Inc. (EG&G), "Response to your Request for Additional Information on the Adequacy of Station Electric Distribution System Voltages," March 19, 1981, ND-81-0076.

4. Telecon, A. Udy, EG&G Idaho and J. Reesy, PSC, March 27, 1981.

5. PSC letter, F. E. Swart to A. Udy, EG&G Idaho, "Response to your Request for Additional Information on the Adequacy of Station Electric Distribution System Voltages," April 7, 1981, ND-81-0089.

6. PSC letter, H. L. Brey to A. Udy, EG&G Idaho, "Load Flow Analysis of Fort St. Vrain 4160V and 480V Buses," July 6, 1981, ND-81-0164.

7. PSC letter, H. L. Brey to G. Kuzmycz, NRC, "Electrical Power Systems," May 28, 1982.

8. PSC letter, H. L. Brey to G. Kuzmycz, NRC, "Electrical Power Systems," June 7, 1982.

9. Telecon, A. Udy, EG&G Idaho, and M. Niehoff, PSC, June 14 and 16, 1982.