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# TECHNICAL EVALUATION REPORT, ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES, JOSEPH M. FARLEY NUCLEAR POWER STATION, UNIT NOS. 1 AND 2, DOCKET NOS. 50-348 AND 50-364

D. A. Weber

NRC Research and Technical Assistance Report

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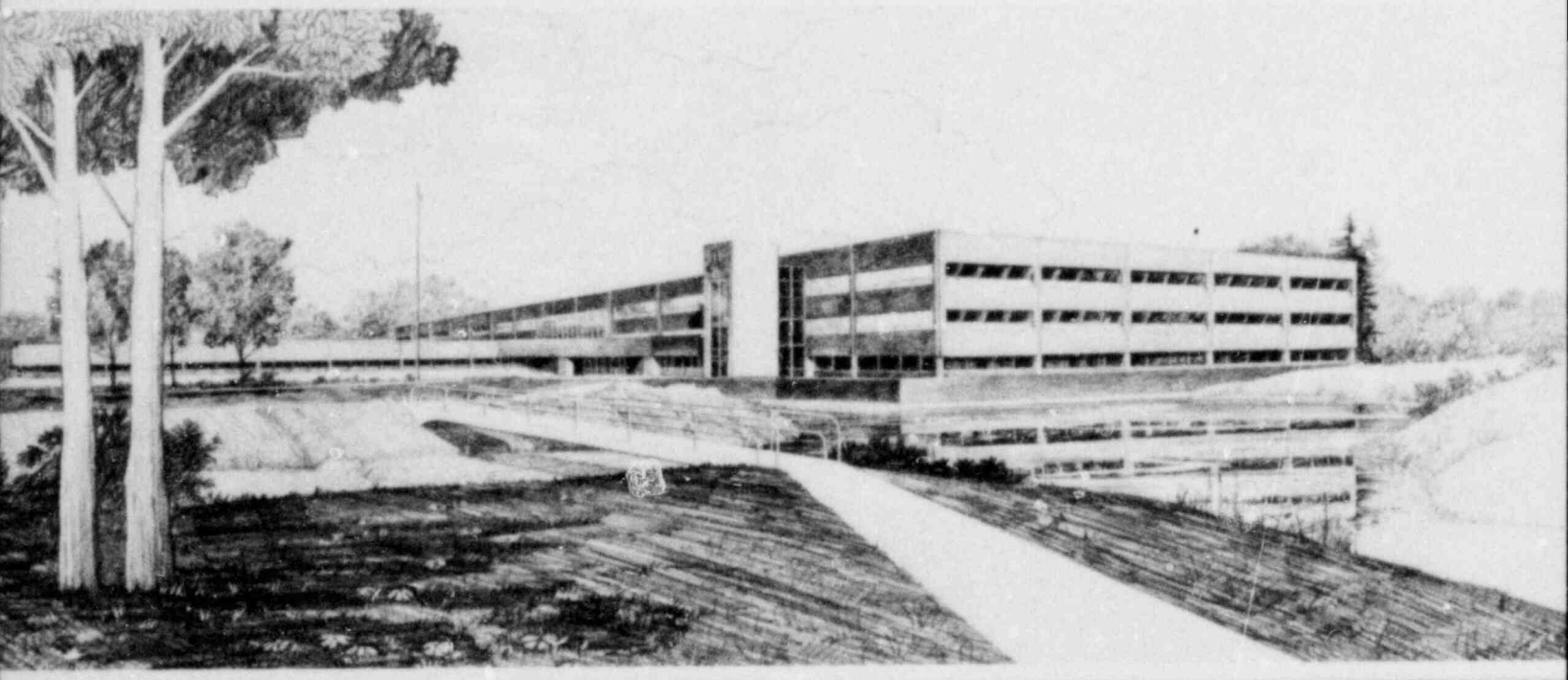

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INTERIM REPORT

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# ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

## JOSEPH M. FARLEY NUCLEAR POWER STATION - UNIT NOS. 1 AND 2

Docket Nos. 50-348 and 50-364

January 1981

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Reliability and Statistics Branch
Engineering Analysis Division
EG&G Idaho, Inc.

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## ABSTRACT

The Nuclear Regulatory Commission has required all licensees to analyze the electric power system at each nuclear station. This review is to determine if the onsite distribution system in conjunction with the offsite power sources has sufficient capacity and capability to automatically start and operate all required safety loads within the equipment voltage ratings. This Technical Evaluation Report reviews the submittals for the Joseph M. Farley Nuclear Power Station.

The offsite power sources, in conjunction with the onsite distribution system, has been shown to have sufficient capacity and capability to continuously operate all required safety related loads, within the equipment rated voltage limits, in the event of either an anticipated transient or an accident condition.


## FOREWORD

This report is supplied as part of the selected Electrical, Instrumentation, and Control Systems (EICS) 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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FIGURE



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ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

JOSEPH M. FARLEY NUCLEAR 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.

In response to the NRC generic letter, Alabama Power Company (APC) submitted a voltage analysis on December 11, 1979.[2] This review is based on this submittal, APC's submittals on November 7, 1977,[3] January 15, 1979,[4] May 1, 1980,[5] July 17, 1980[6], July 30, 1980[7], August 7, 1980[8], October 7, 1980[9], NRC memorandum of July 25, 1980[10] and August 13, 1980[11], and the Final Safety Analysis Report (FSAR).

Based on the information supplied by APC, this report addresses the capacity and capability of the onsite distribution system of the Joseph M. Farley Nuclear 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.



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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.

## 3.0 SYSTEM DESCRIPTION

A single-line diagram of the AC electrical system at Farley Unit 1 is shown in Figure 1. The Farley Unit 2 is similar.

Two startup auxiliary transformers, connected to the 230kV switchyard supply the load of the 4.16 kV buses H, K, and F of train A (transformer 1A) and G, L, and J of train B (transformer 1B). Either transformer can supply both trains.

Each unit is provided with seventeen 600V load centers and thirteen 600V and 208V motor-control centers. Seven of the load center and eleven of the motor control centers are shared between the units, and can be supplied from either the Unit 1 or Unit 2 distribution system. All class 1E 600V buses and loads are supplied from the 4160V 1E buses.

Table 1 shows the operating ratings and settings of equipment at the Farley Station.

## 4.0 ANALYSIS DESCRIPTION

4.1 Analysis Conditions. APC has determined by grid stability analysis that the maximum expected 230kV offsite grid voltage is 241.27kV (104.9%) and the minimum 229.54kV (99.8%).

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

1. The 230kV switchyard is at the maximum expected voltage.

2. Unit 1 is on post-LOCA after plant shutdown with lighting and HVAC loads running.

3. Unit 2 is in the refueling mode with lighting and HVAC loads running.

The worst case minimum voltage conditions occur when:

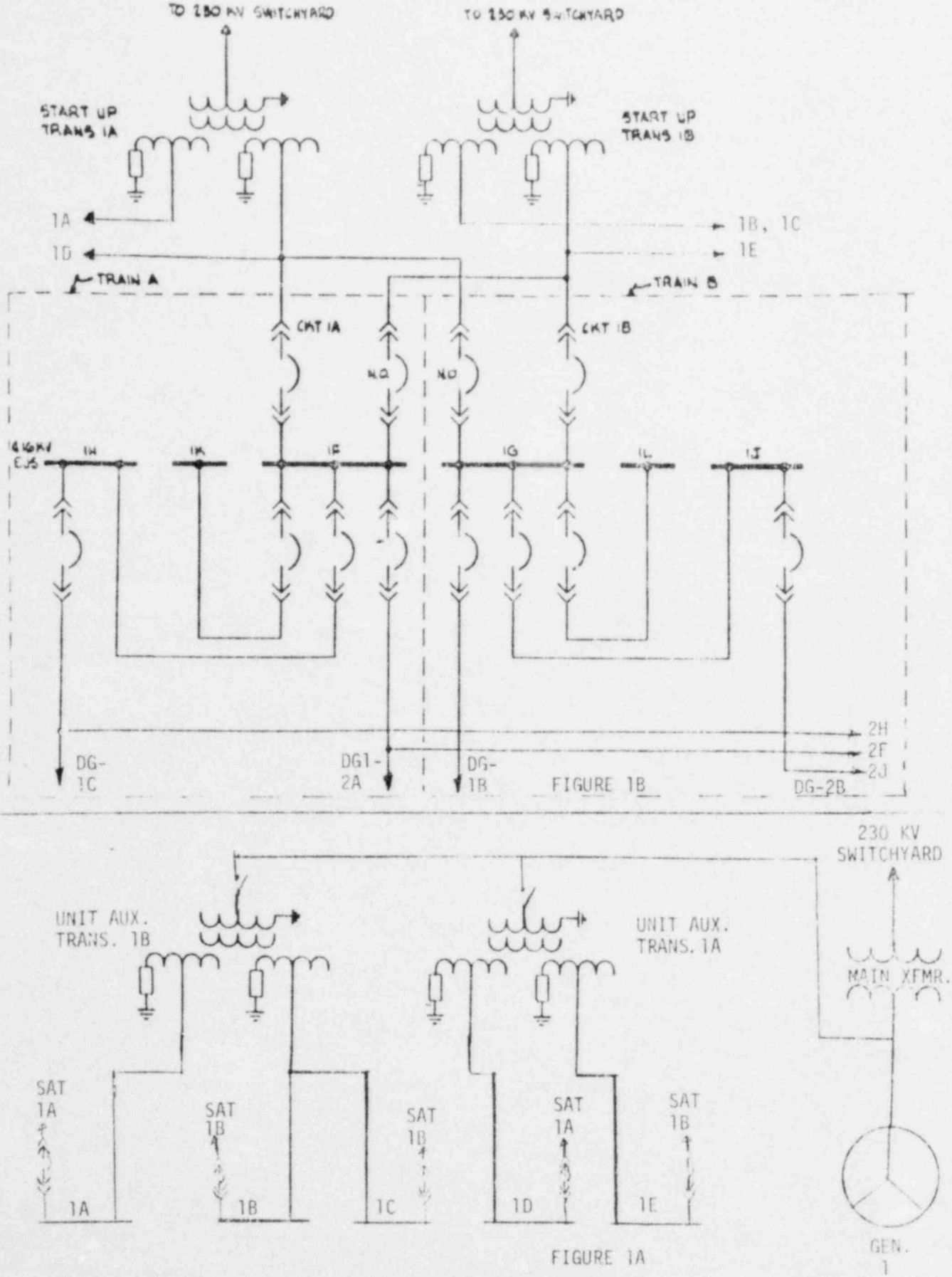


FIGURE 1. FARLEY ELECTRIC DISTRIBUTION SYSTEM

TABLE 1

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

| | | Maximum[a] | | Minimum[a] | | |
|---|---|---|---|---|---|---|
| | | | | | Analyzed | |
| Equipment | Condition | Rated | Analyzed | Rated | Steady State | Transient |
| 4000V Motors | Start | -- | -- | 75 | -- | 88.71 |
| | Operate | 110 | 106.36 | 90 | 92.99 | -- |
| 550V Motors | Start | -- | -- | 75 | -- | 77.75 |
| | Operate | 110 | 110.39 | 90 | 93.57 | -- |
| 200V Motors | Start | -- | -- | 75 | -- | 76.27 |
| | Operate | 110 | 110.36 | 90 | 92.9 | -- |
| 600V Starters (MCCs) | Pickup | -- | -- | 71 | -- | 71.27 |
| | Dropout | -- | -- | 55 | -- | 71.27 |
| | Operate | 110 | 101.19 | 85 | 85.77 | -- |
| 208V Starters (MCCs) | Pickup | -- | -- | 71 | -- | 73.86 |
| | Dropout | -- | -- | 55 | -- | 73.86 |
| | Operate | 110 | 106.11 | 85 | 89.32 | -- |
| 120V Other Equipment | 120V | 110 | b | 90 | b | b |

a. 230kV switchyard: maximum 104.9%, minimum 99.8%.

b. All lower voltage instrumentation and other equipment are supplied from inverters/regulated transformers.

1. The 230kV switchyard is at its minimum expected voltage.

2. Unit 1 unit transformers are out of service.

3. Unit 1 is in a LOCA condition with all possible Unit 1 loads and all possible Unit 2 shutdown and normal loads supplied from both Unit 1 startup auxiliary transformers 1A and 1B.

The worst case transient condition occurs with the start of a 3,000 hp Condensate Pump coincident with the start of the LOCA loads.

4.2 Analysis Result. Table 1 shows the projected worst case class 1E equipment terminal voltages, and Table 2 shows a comparison of analyzed voltage and undervoltage relay setpoints.

TABLE 2

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

| Location/Relays | Minimum Analyzed | | Relay Setpoint | |
|---|---|---|---|---|
| | Voltage | Time | Voltage (Tolerance) | Time |
| 4160V bus 1F[a] | | | | |
| Degraded grid | 89.65 | continuous | 89.65 (±1) | 20-30 sec |
| Loss of grid | 75.97 | 6 sec | 72.00 | 3.6 sec |

a. APC submitted voltages and location of U/V and LOV relays.

4.3 Analysis Verification. The voltage analysis provided by APC in their submittal of December 11, 1979,[2] is for Unit 1. However, since Unit 1 is presently operating, a test was performed on Unit 2. The string of buses monitored on Unit 2 are similar to the buses analyzed for Unit 1.

In regard to Unit 1 testing, the licensee has submitted[9] detailed acceptable justification supporting the applicability of the Unit 2 testing, combined with the prior Unit 1 test[2], for verifying the Unit 1 design.

The details of the test[8,9,11] to verify the results are as follows:

1. APC measured Train B safeguards equipment electrical parameters (V, KW, KVAR) at the 230kV switchyard, 4160V Bus 2G (supplied by Startup Transformer 2B), 600V Load Center 2E, and the 600V and 208V Motor Control Centers 2T. This string of buses has been determined by analysis to exhibit the largest voltage drops during the worst case analyzed. Nearly 100% of the Train B loads were in operation, as well as the 7000 hp circulating water pump on the 4160V Bus 2A. The total load recorded is approximately 33% of the total load on Startup Transformer 2B due to a unit trip with safety injection.

2. The test data for each bus was converted from KW and KVAR to KVA and power factor, and these values along

with the measured switchyard voltage were input to the computer. The bus voltages were than calculated using the same analytical model that was used in the worst case analysis. The test and calculated voltage were then compared and the differences noted. Justification for differences between the analytical and test results, including measurement errors, was also provided.

## 5.0 EVALUATION

Six 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.

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

APC has shown, by analysis, that each offsite source and distribution system connection combination has sufficient capability and capacity for starting and continuously operating the class 1E loads within the equipment voltage ratings (Table 1).

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.

The licensee's analysis indicates that the voltage for the 550V and 200V motors will be less than 1/2% above the maximum allowable value for these motors. This small of an increase over the 110% rating of the motor will not significantly affect their continuous operation. The voltage for the other class 1E equipment will be within their ratings. Therefore, the voltages will satisfy the requirements as expressed in the above position.

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.

Under transient conditions (Table 2), it appears that the minimum voltage comes close to the setpoints for both the degraded grid and loss-of-voltage relays. This is based on transferring the worst case minimum 4160V bus voltage of 75.97% from the Case A3 analysis[2] to Figure 2 of APC's July 17, 1980,[6] submittal (which shows the CV-2 loss-of-voltage and degraded grid voltage relay curves) with an assumed six-second transient time for the start of a Condensate Pump (noted in Figure 1 of the January 15, 1979,[4] submittal).

This position is satisfied based on APC's conservative analysis which shows a transient condition for the simultaneous start of all LOCA loads coincident with the start of a Condensate Pump. Loss of offsite power to

the class 1E distribution system is not expected to occur due to operation of the voltage protection relays. However, it is recommended that the licensee institute plant procedures limiting the start of a Condensate Pump when the voltage on 4160V 1E buses fall below 3800V (91%), and the LOCA loads are starting.

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

The test procedure and results have been reviewed and found acceptable.

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).

APC has analyzed the onsite distribution system connections to the offsite power grid, and determined that no potential exists for simultaneous or consequential los 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.

Each unit is independently connected to offsite power sources and have some common electrical power interconnections between units at the 600V load centers and 600V motor control centers. APC's analysis considers an accident in Unit 1 (LOCA) and the simultaneous shutdown of Unit 2 has demonstrated the adequacy of starting and operating voltages for all required class 1E loads. Under these conditions, the analyzed voltages are within the equipment ratings.

## 6.0 CONCLUSIONS

The voltage analyses submitted by the Alabama Power Company for Joseph M. Farley Nuclear Power Station were evaluated in Section 5 of this report. It has been determined 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.

2. The test results verified the analysis accuracy.

3. Justification supporting the applicability of the Unit 2 testing, combined with the prior Unit 1 test[2], for verifying the Unit 1 design is acceptable.

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

5. 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.

It is recommended that the licensee institute plant procedures limiting the start of a Condensate Pump when the voltage on 4160V 1E buses fall below 3800V, and the LOCA loads are starting.

## 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. APC letter, F. L. Clayton, Jr., to U. S. Nuclear Regulatory Commission, dated December 11, 1979.

3. APC letter, J. T. Young, to U. S. Nuclear Regulatory Commission, dated November 7, 1977.

4. APC letter, F. L. Clayton, Jr., to U. S. Nuclear Regulatory Commission, dated January 15, 1979.

5. APC letter, F. L. Clayton, Jr., to U. S. Nuclear Regulatory Commission, dated May 1, 1980.

6. APC letter, F. L. Clayton, Jr., to U.S. Nuclear Regulatory Commission, dated July 17, 1980.

7. APC letter, F. L. Clayton, Jr., to U.S. Nuclear Regulatory Commission, dated July 30, 1980.

8. APC letter, F. L. Clayton, Jr., to U.S. Nuclear Regulatory Commission, dated August 7, 1980.

9. APC letter, F. L. Clayton, Jr., to U.S. Nuclear Regulatory Commission, dated October 7, 1980.

10. NRC memorandum, P. S. Check, to T. Novak and R. T. Tedesco, "Updated Safety Evaluation, Degraded Grid Voltage Protection for the Class 1E A.C. Power Systems," July 25, 1980.

11. NRC memorandum, P. S. Check, to T. Movack and R. T. Tedesco, "Updated Safety Evaluation, Degraded Grid Voltage Protection for the Class 1E A.C. Power System," August 13, 1980.