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TECHNICAL EVALUATION OF THE ADEQUACY OF STATION
ELECTRIC ~~DISTRIBUTION~~ ~~SYSTEM~~ VOLTAGES FOR THE
CALVERT CLIFFS NUCLEAR POWER PLANT
UNITS 1 AND 2

James C. Selan

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ABSTRACT

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This report documents the technical evaluation of the adequacy of the station electric distribution system voltages for the Calvert Cliffs Nuclear Power Plant, Units 1 and 2. The evaluation is to determine if the onsite distribution system in conjunction with the offsite power sources has sufficient capacity to automatically start and operate all Class 1E loads within the equipment voltage ratings under certain conditions established by the Nuclear Regulatory Commission. The analyses submitted demonstrate that adequate voltage will be supplied to the Class 1E equipment under worst case conditions.

FOREWORD

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TECHNICAL EVALUATION OF THE
ADEQUACY OF STATION ELECTRIC
DISTRIBUTION SYSTEM VOLTAGES
FOR THE CALVERT CLIFFS NUCLEAR POWER PLANT
UNITS 1 AND 2

(Docket Nos. 50-317, 50-318)

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1. INTRODUCTION

The Nuclear Regulatory Commission (NRC) by a letter dated August 8, 1979 [Ref. 1] expanded its generic review of the adequacy of the station electric distribution systems for all operating nuclear power facilities. 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. In addition, the NRC requested each licensee to follow suggested guidelines and to meet certain requirements in the analysis. These requirements are detailed in Section 5 of this report.

By letters dated October 8, 1979 [Ref. 2], June 20, 1980 [Ref. 3], March 31, 1981 [Ref. 4], November 24, 1981 [Ref. 5], and March 11, 1982 [Ref. 6], Baltimore Gas and Electric Company (BGECo), the licensee, submitted their analysis and conclusion regarding the adequacy of the electrical distribution system's voltages at Calvert Cliffs Nuclear Power Plant, Units 1 and 2.

The purpose of this report is to evaluate the licensee's submittal with respect to the NRC criteria and present the reviewer's conclusion on the adequacy of the station electric distribution systems to maintain the voltage within the design limits of the required Class 1E equipment for the worst case starting and load conditions.

2. DESIGN BASIS CRITERIA

The design basis criteria that were applied in determining the adequacy of station electric distribution system voltages to start and operate all required safety loads within their required voltage ratings are as follows:

- (1) General Design Criterion 17 (GDC 17), "Electric Power Systems," of Appendix A, "General Design Criteria for Nuclear Power Plants," in the Code of Federal Regulations, Title 10, Part 50 (10 CFR 50) [Ref. 7].
- (2) General Design Criterion 13 (GDC 13), "Instrumentation and Control," of Appendix A, "General Design Criteria for Nuclear Power Plants," in the Code of Federal Regulations, Title 10, Part 50 (10 CFR 50) [Ref. 7].
- (3) General Design Criterion 5 (GDC 5), "Sharing of Structures, Systems and Components," of Appendix A, "General Design Criteria for Nuclear Power Plants," in the Code of Federal Regulations, Title 10, Part 50 (10 CFR 50) [Ref. 7].
- (4) ANSI C84.1-1977, "Voltage Ratings for Electric Power Systems and Equipment" [Ref. 8].
- (5) IEEE Std 308-1974, "Class 1E Power Systems for Nuclear Power Generating Stations" [Ref. 9].
- (6) "Guidelines for Voltage Drop Calculations," Enclosure 2, to NRC letter dated August 8, 1979 [Ref. 1].

3. SYSTEM DESCRIPTION

An electrical one-line diagram of Calvert Cliffs Nuclear Power Plant, Units 1 and 2, is shown in Figure 1. Each of the generating units are connected to a common 500 kV switchyard. The onsite distribution system for both units is supplied by two service transformers (P13000-1 and P1300-2) from the 500 kV switchyard. Current Technical Specifications (3/4.8.1, Amendment No. 58) allows for the substitution of the 69 kV Southern Maryland Electric Cooperative (SMECO) line if one of the two 500 kV offsite sources is out of service. The 69 kV SMECO line ties onto 13 kV bus No. 23 from which 4160-volt Class 1E buses No. 11 and 24 will be fed from via 13 kV bus No. 11. The capacity of the 69 kV line is to supply a full complement of essential loads for one unit under LOCA conditions and the essential equipment to attain and maintain a safe shutdown in the other unit. The swing of the 69 kV line is maintained at $\pm 1\%$ by the use of a voltage regulator. There are no automatic transfers of loads from one transformer to another. The

FIGURE 1 CALVERT CLIFFS, UNITS 1 & 2 - CLASS 1E ELECTRICAL ONE-LINE DIAGRAM

unit generators do not carry any plant loads as neither unit has an auxiliary transformer. The Class 1E distribution systems are supplied by four service transformers from the 13.8 kV system. There are four 4160-volt Class 1E buses (two per unit). Each 4160-volt Class 1E bus can be fed from either of the two service transformers. The 480-volt Class 1E buses are in return fed from the 4160-volt Class 1E buses through their respective service transformers.

The Class 1E equipment is protected from undervoltage conditions by two protection levels. The first level (loss of voltage) scheme has setpoints of 2450 volts + 105 volts (59% of 4160 volts) with a time delay of 2 seconds + 0.2 seconds. The second level (degraded voltage) scheme has setpoints of 3628 volts + 25 volts (87.2% of 4160 volts) with a time delay of 8 seconds + 0.4 seconds. The undervoltage protection schemes are located on each 4160-volt Class 1E bus. All the Class 1E 4000-volt and 460-volt motors have a service factor rating of 1.15 except for six motors (four at 1.0, one at 1.2, and one at 1.37).

4. ANALYSIS

4.1 ANALYSIS CONDITIONS

Baltimore Gas and Electric Company analyzed each 500 kV offsite source to the onsite distribution system under minimum and maximum load conditions in conjunction with minimum and maximum grid voltages to determine the voltage at the Class 1E equipment terminals. The analyses utilized a computer load flow program supplemented by additional calculations to analytically determine terminal voltages for various plant operating scenarios. The minimum and maximum expected grid voltage used is 97% and 103% of the 500 kV nominal, respectively. The largest load demand condition is with full load plant auxiliaries during actuation of the engineered safety features (ESF). Automatic bulk loading on the offsite sources with ESF loads was evaluated. The full auxiliary plant load was derived from actual load measurements. The 69 kV SMECO line was analyzed using the nominal voltage of 69 kV with an accident condition at Unit 1 and Unit 2 in a shutdown condition. Load sequencing is utilized when using the 69 kV SMECO line. In addition to the above analysis conditions, the starting of large non-Class 1E loads were also analyzed.

4.2 ANALYSIS RESULTS

The worst case Class 1E equipment voltages occur under the following conditions:

4.2.1 Overvoltage

All auxiliary loads under normal shutdown, grid at 103% of 500 kV nominal.

4.2.2 Undervoltage

Full auxiliary plant load at both units with engineered safety features starting and running at Unit 1, grid voltage at 100% of 500 kV nominal, only one service transformer is operational.

These worst case Class 1E equipment voltages are shown in Table 1.

As a result of the voltage analyses and tests, Baltimore Gas and Electric Company made several corrective measures and identified some operating limits to ensure adequate voltage. The corrective measures made were the replacement of 120-volt control circuit fuses to a higher rating in certain motor contactor circuits and the replacement of some control transformers to bring contactor coil voltage within acceptable pickup values. The control circuit fuses for size 3 starters were replaced with 4 amp fuses and for size 4 starters with 6 amp fuses. Control transformers for size 2 starters were replaced with a 150 VA rating and 350 VA rating for the size 3 starters [Ref. 5]. The operating limits identified relating to plant loading and grid voltage conditions are as follows:

- (1) The allowable voltage range for the grid during normal operation with only one service transformer in service is 100% to 103% of 500 kV nominal [Ref. 4].
- (2) To start a large non-Class 1E load with both units at full load and ESF loads running and only one service transformer in service, the grid must be adjusted to 103% of the 500 kV nominal prior to the non-Class 1E load start [Ref. 4].

4.3 ANALYSIS VERIFICATION

Baltimore Gas and Electric Company conducted voltage profile tests during full ESF testing to verify the accuracy of the calculations. The tests made were as follows:

- (1) A fourth reactor coolant pump was started while three were running and the grid was at 97% of nominal. The voltage was measured at the 4 kV bus. The starting voltage dropped to 95% of the initial steady state voltage. Comparing the actual test results to the computer calculations (Case 1 and Case 2 of Ref. 2) also shows a voltage drop percentage of 95% ($.8951 \div .9418 = .95$) which produces an error percentage of 0.0%.
- (2) A condensate booster pump was started with the grid at 97% of nominal. The measured starting voltage dropped to 92.3% of the initial steady state voltage. Comparing actual test results to the computer calculations (Case 1 and Case 4 of Ref. 2) shows a voltage drop percentage of 91.7% ($.8638 \div .9418 = .917$) which produces an error percentage of .6%.

TABLE 1

CALVERT CLIFFS NUCLEAR POWER PLANT, UNITS 1 AND 2
 CLASS 1E EQUIPMENT VOLTAGE RATINGS AND ANALYZED
 WORST CASE TERMINAL VOLTAGES
 (in % of Equipment Nominal Voltage Rating)

Equipment	Nominal Voltage Rating (100 %)	Maximum		Minimum	
		Rated	Analyzed	Rated	Analyzed (a)
			Steady State		Steady State Transient
Motors	4000				
Start				75	
Operate		110	105.8	90	89.3(b) 82.2
	460				
Start				75	
Operate		110	107.8	90	87(b) 75
Contactors	120				
Pickup				84.5	87
Dropout		65			
Operate		110	107.4	70	87 76
Other(c) Equipment					

(a) Analysis assumes automatic bulk loading on the offsite sources.

(b) These values which are slightly below design limits are the analyzed worst case. However, for actual plant conditions, non-essential loads will be tripping off at the accident unit while the remaining unit is placed in an orderly shutdown, thus ensuring that the voltages will fall within the design ratings. Also, incorporating the percentage errors from the test verification into the results presented, demonstrate that the voltages at the Class 1E equipment will be within the voltage design ratings for the worst case.

(c) Class 1E 120-volt AC panels are supplied from 125-volt station batteries through inverters.

In addition to the above tests, three other tests were made during an ESF test [Ref. 3]. The tests involved comparing calculated values to actual measured values for auxiliary loads running (Case 1), running auxiliary loads with starting ESF loads (Case 5), and running auxiliary and ESF loads (Case 6). The highest percentage error for the three cases at the 4160-volt and 480-volt levels were 5% and 5.7%, 6.6% and 1.5%, and 5.8% and 6.3% respectively. All the measured values were higher than the calculated values which indicates the results of the analyses to be highly conservative.

5. EVALUATION

The NRC generic letter [Ref. 1] stated several requirements that the plant must meet in their voltage analysis. These requirements and an evaluation of the licensee's submittals are as follows:

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

The analysis submitted shows that when both 500 kV service transformers are in service, the Class 1E equipment will be capable of automatically starting and continuously operating within the voltage design ratings under the worst case conditions. With only one 500 kV service transformer operational, the analysis demonstrates that for an accident in one unit while maintaining full load auxiliaries on the second unit, a grid voltage limit of 100% of the 500 kV nominal is required to ensure acceptable starting and operating voltage. However, during this actual scenario, non-essential loads would be tripping off at the accident unit while the remaining unit would be placed in an orderly shutdown. For this condition (loss of both generating units and load reduction), the operating limit of 100% would be reduced to near the normal grid swing. Any voltage degradation below the equipment design limits will cause the undervoltage protection scheme to actuate [Ref. 10]. The analysis for the 69 kV SMECO line demonstrated that it has the capacity and capability to supply adequate voltage for an accident condition in one unit and an orderly shutdown of the remaining unit.

- (2) With the maximum expected offsite grid voltage and minimum load condition, each offsite source and distribution system connection must be capable of continuously operating the required Class 1E equipment without exceeding the equipment's voltage ratings.

The analysis shows that for maximum grid voltage and minimum plant load, the voltage at the Class 1E equipment does not exceed the design ratings.

- (3) The analysis must show that there will be no spurious separation from the offsite power source to the Class 1E buses by the voltage protection relays when the grid is within the normal expected limits and the loading conditions established by the NRC are being met.

To preclude spurious trips when starting a large non-Class 1E load, the analysis showed that for the conservatively worst case when only one 500 kV service transformer is operational, both units at full auxiliary load, and accident loads running at one unit, the grid must be at 103% of nominal. However, in the actual scenario, non-essential loads in the accident unit could be tripping off while the remaining unit would be in an orderly shutdown. This reduction in loading would decrease the voltage drop experienced at the Class 1E buses thus lowering the operating limit of 103% to near the normal grid swing. Therefore, the starting transient of a large non-Class 1E load would not cause spurious tripping [Ref. 10].

- (4) Test results are required to verify the voltage analyses calculations submitted.

The licensee performed tests which verified that the analysis results submitted were conservative and are acceptable.

- (5) Review the plant's electrical power systems to determine if any events or conditions could result in the simultaneous loss of both offsite circuits to the onsite distribution system (compliance of GDC 17).

The licensee analyzed the connections to the onsite distribution system and has determined that no potential exists for the simultaneous or consequential loss of both required circuits from the offsite grid [Ref. 11].

- (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 to all required Class 1E loads with an accident in one unit and a safe shutdown in the remaining unit(s).

The licensee demonstrated that the shared offsite sources have the capacity and capability to provide adequate voltage to the Class 1E equipment of both units with an accident in one unit and an orderly shutdown of the other unit.

6. CONCLUSIONS

Based on the information submitted by Baltimore Gas and Electric Company for the Calvert Cliffs Nuclear Power Plant, Units 1 and 2, it is concluded that:

- (1) The offsite power sources in conjunction with the onsite distribution system, has the capacity and capability to supply voltage to the Class 1E equipment within the voltage design ratings under worst case conditions.
- (2) Spurious tripping from the offsite sources will not occur under worst case conditions.
- (3) The Class 1E equipment's maximum voltage design limit will not be exceeded under maximum grid voltage-minimum plant load conditions.
- (4) Acceptable test verifications were made to verify the analytical data submitted.
- (5) No event or condition will result in the simultaneous or consequential loss of both required circuits to the onsite distribution system.

Accordingly, I recommend that the NRC accept the voltage analyses submitted which demonstrates the adequacy of voltage to the Class 1E equipment for starting and continuous operation under worst case conditions.

REFERENCES

1. NRC letter (W. Gammill) to all power reactor licensees, dated August 8, 1979.
2. Baltimore Gas and Electric Company letter (Arthur E. Lundvall, Jr.) to NRC (Darrell G. Eisehut), dated October 8, 1979.
3. Baltimore Gas and Electric Company letter (R. C. L. Olson) to NRC (Robert A. Clark), dated June 20, 1980.
4. Baltimore Gas and Electric Company letter (Arthur E. Lindvall, Jr.) to NRC (Robert A. Clark), dated March 31, 1981.
5. Baltimore Gas and Electric Company letter (R. C. L. Olson) to NRC (R. A. Clark), dated November 24, 1981.
6. Baltimore Gas and Electric Company letter (R. C. L. Olson) to NRC (D. H. Jaffe), dated March 11, 1982.
7. Code of Federal Regulations, Title 10, Part 50 (10 CFR 50), General Design Criterion 5, 13 and 17 of Appendix A for Nuclear Power Plants.
8. ANSI C84.1-1977, "Voltage Ratings for Electric Power Systems and Equipment."
9. IEEE STD. 308-1971, "Class 1E Power Systems for Nuclear Power Generating Stations."
10. Telecons, Baltimore Gas and Electric Company (Phil Hebrank and staff), NRC (Dick Prevatte), and LLNL (James C. Selan), dated February 26, 1982 and March 16, 1982.
11. Telecon, Baltimore Gas and Electric Company (Phil Hebrank, Ken Sebra) and LLNL (James C. Selan), dated December 23, 1981.

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