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TECHNICAL EVALUATION REPORT ON THE ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES FOR THE SURRY POWER STATION, UNITS 1 AND 2

(Docket Nos. 50-280, 50-281)

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ABSTRACT

This report documents the technical evaluation of the adequacy of the station electric distribution system voltages for the Surry Power Station, 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 the station's electric distribution system will supply adequate voltage to the Class 1E equipment under the worst case conditions analyzed.

FOREWORD

This report is supplied as part of the Selected Electrical, Instrumentation, and Control Systems Issues Program being conducted for the U. S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Licensing, by Lawrence Livermore National Laboratory.

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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 May 26, 1981 [Ref. 2], December 31, 1981 [Ref. 3], March 31, 1982 [Ref. 4], June 11, 1982 [Ref. 5], and June 30, 1982 [Ref. 6], Virginia Electric and Power Company (VEPCO), the licensee, submitted their analysis and conclusion regarding the adequacy of the electrical distribution system's voltages at the Surry Power Station, 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 for Surry Power Station, Units 1 and 2 is shown in Figure 1. Each unit's generator is connected to the transmission system through it's own main transformer. The output of the the generator is stepped up from 22 kV to 230 kV and 22 kV to 500 kV for Units 1 and 2, respectively. The 230 kV system and the 500 kV system is tied together by two 500/230/36.5 kV autotransformers (preferred offsite source). The autotransformers supply two 34.5 kV buses from which the three 34.4/4.16 kV reserve station service transformers (RSST's), two 34.4/4.16 kV intake structure transformers and four 34.5 kV reactor banks are fed. The RSST's A, B, and C supply the 4 kV transfer buses D, E, and F respectively. Transfer bus D supplies Class 1E bus 1J and station service buses 1A and 2A. Transfer bus E supplies

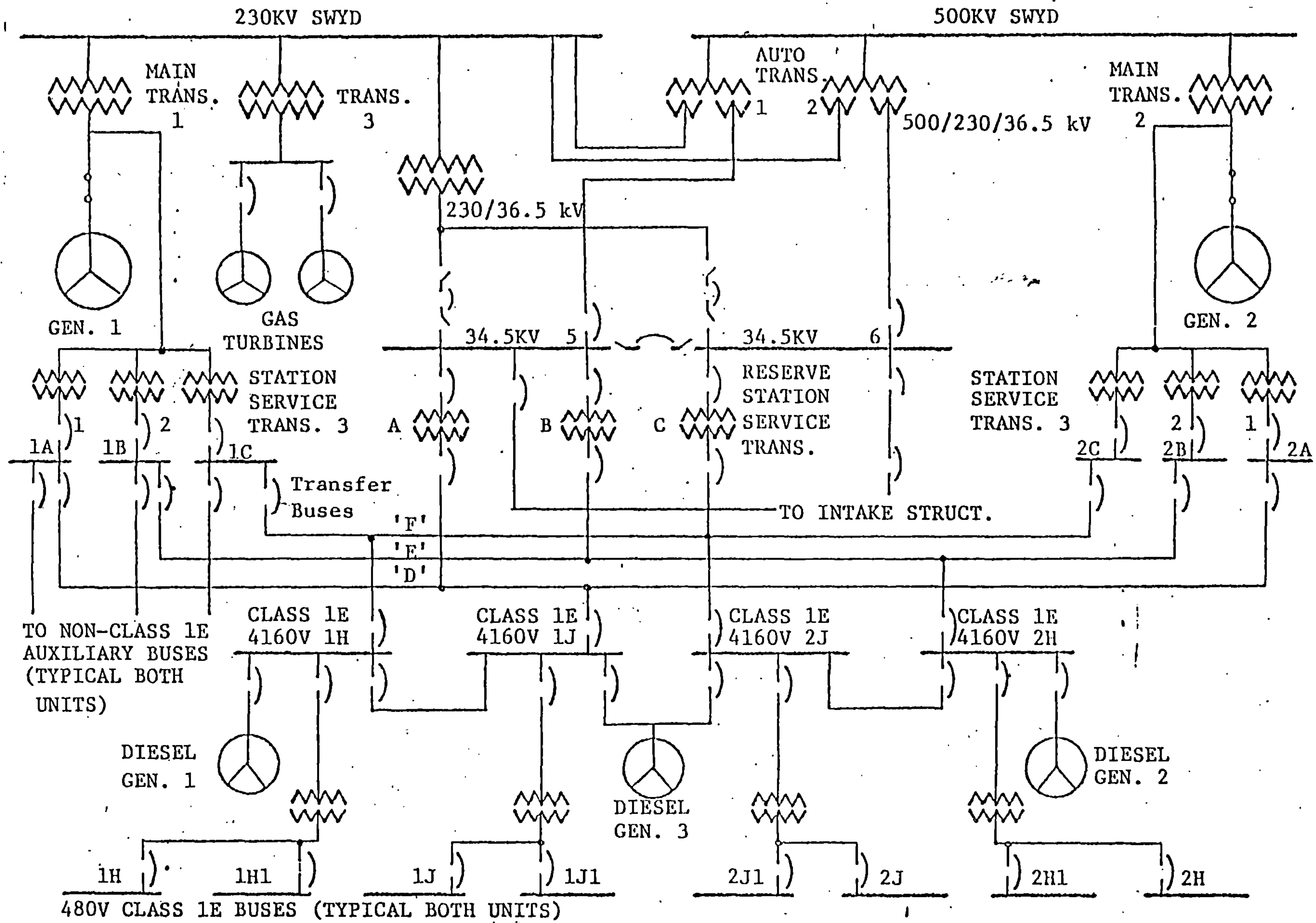

FIGURE 1 - SURRY UNITS 1 AND 2 - ELECTRICAL ONE-LINE DIAGRAM

Class 1E bus 2H and station service buses 1B and 2B. Transfer bus F supplies Class 1E buses 1H and 2J and station service buses 1C and 2C. The Class 1E buses (two 4160-volt and four 480-volt Class 1E buses at each unit) are fed from the RSST's at all times. The RSST's have a load tap changer (LTC) on their secondary winding which is set to maintain a 4300-volt output and which will provide a ± 10% voltage adjustment over the full range of operation. The adjustment capability is provided by 32 taps each of 0.625% voltage adjustment.

The station service buses are normally fed from the 22/4.16 kV station service transformers which are supplied by the main generator. During plant startup, the station service buses are then supplied from the RSST's. A unit trip will initiate an automatic transfer of the station service buses to the RSST's.

The 230/36.5 kV transformer which is supplied from the 230 kV switchyard serves as an alternate supply to the reserve station service system. On loss of either 500/230/36.5 kV autotransformer, the alternate supply is automatically switched to supply the affected 34.5 kV bus. The 230/36.5 kV transformer is equipped with a LTC on the secondary winding which is set to maintain 36.4 kV and will provide a ± 10% voltage adjustment over the full range of operation. The adjustment capability is provided by 32 taps each of a 0.625% voltage adjustment.

The Class 1E equipment will be protected from undervoltage conditions by two protection schemes. The first scheme (loss of voltage) consists of three undervoltage relays (2-out-of-3 logic) on each 4160-volt Class 1E bus. The loss-of-voltage relays are set to actuate at a voltage setpoint of 75% ± 0.1% of 4160 volts (3120 volts) with a time delay of 2 seconds, + 5 seconds, - 0.1 seconds. The degraded voltage scheme consists of three undervoltage relays (2-out-of-3 logic) on each 4160-volt Class 1E bus. These relays are set to actuate at 90% ± 1% of 4160 volts (3744 volts). The time delay associated with the voltage setpoint is 7 ± 0.35 seconds for a safety injection (SI) or a consequence limiting safeguard (CLS) and 60 ± 3 seconds for non-CLS or non-SI conditions.

4. ANALYSIS

4.1 ANALYSIS CONDITIONS

VEPCO has analyzed each of the offsite circuits to the reserve station service system from which the Class 1E buses are fed through the RSST's. Various loading conditions were analyzed which included combinations of the units at 100% power, startup, tripping, tripping with a CLS, and refueling. From these various loading combinations under minimum and maximum offsite grid voltages of 505 kV and 535 kV respectively, the RSST system was analyzed to ensure the system can supply adequate voltage to the Class 1E equipment. The analysis included several assumptions to ensure the "worst case" was analyzed and are as follows:

(1) The maximum switchyard voltage drop caused by either one or both of the units tripping off-line is 15 kV. The load tap changer tap position is determined by the loading on the RSST's prior to the condition analyzed and with the switchyard voltage at 520 kV. At the instant the condition being analyzed occurs, the switchyard voltage drops instantaneously to 505 kV and the loading caused by the condition is assumed to occur. Voltages calculated at this time are based on the LTC tap position prior to the condition occurrence. Final voltages are based on the LTC correcting for the loading with the switchyard still at 505 kV.

(2) Transferring of the station service buses (non-Class 1E) to the reserve station service system occurs immediately upon occurrence of the condition being analyzed.

(3) All motors receiving an SI or CLS signal were assumed not to be running prior to the accident. Upon receiving the signal, all motors were assumed to start.

(4) Worst case loading of the station service buses was assumed for the transfers.

(5) No manual load shedding or reduction in motor current due to decreased pump loads is assumed to occur for 1 hour after the occurrence analyzed.

(6) Sequence loading occurs as designed. The sequenced loads are the auxiliary steam generator feedwater pumps (50 seconds after an SI signal), inside recirculation spray pump (120 seconds after an SI signal), and the outside recirculation spray pump (300 seconds after an SI signal).

(7) The existing load-shedding scheme on each individual RSST occurs as designed. The affected loads are tripped and locked out [Ref. 4].

(8) Ampere values used were measured values except for those which had to be estimated.

(9) Anticipated modifications and operating restrictions were included in the analysis except for the replacement of the 4 kV underground cables from the RSST's. Also analyzed was the effect of starting large non-Class 1E loads during steady state conditions following an SI or CLS occurrence.

4.2 ANALYSIS RESULTS

As a result of the initial analyses of the various loading combinations, several modifications and operating restrictions were determined necessary to eliminate equipment overloading and to assure that adequate voltage is supplied by the RSST system. These modifications and restrictions are as follows:

(1) The existing load shedding scheme which occurs automatically when two units load onto the RSST's will be enabled when one unit is on line and the other unit is in startup, both units on line, and both units in startup.

(2) Follow the transmission system voltage regulation action plan.

(3) Disconnects on both sides of the 34.5 kV bus tie breaker will be normally open to prevent the loss of both offsite source circuits should the tie breaker fail.

(4) Rerate the MOV's starting capability to 80% of 460 volts. If the MOV's cannot be rerated, replace those with MOV's rated at 80% of 460 volts.

(5) Automatically trip the four 34.5 kV reactor banks following an SI or CLS on either unit when the station service buses (non-Class 1E) are transferred to the RSST's.

(6) Modify the LTC control to provide:

(a) Instantaneous voltage correction for approximately 3 minutes upon an SI or CLS at either unit.

(b) Instantaneous voltage correction for approximately 1 minute when a unit transfers to the RSST's during an SI or CLS.

(7) Block the automatic starting of the condensate, high pressure heater drain, bearing cooling and component cooling pumps for approximately 315 seconds after an SI or CLS occurs. The blocking feature is accomplished by the use of auxiliary relays initiated from the SI contacts and will occur in the automatic close path of the pump's 4 kV breakers. The automatic starting is again enabled after the 315 seconds.

(8) Replace and reroute the underground 4 kV cable from the RSST's to the transfer buses.

(9) Add two radiators with fans to each RSST to increase their 55° C rise rating to 30 MVA from 24 MVA.

(10) Replace control transformers (480/120 volt) to larger sizes for adequate voltage to the MOV contactor coils.

(11) Change all the 4160/480-volt transformer taps to 4056/480-volts.

(12) Reroute the RSST control cables to meet the separation requirement for fire protection.

(13) Install overload alarms of 85 MVA and 95 MVA on the 500/230/36.5 kV and 230/36.5 kV transformers.

Based on the above assumptions and including the modifications and operating restrictions into the final analysis, the worst case Class 1E equipment terminal voltages occur under the following conditions and are summarized in Table 1:

4.2.1 Overvoltage

The offsite grid voltage at 535 kV, Unit 1 at 100% power, Unit 2 in refueling, Unit 1 loading on the RSST's consists of Class 1E bus loads only, Unit 2 loading on the RSST's consists of Class 1E bus loads and some 480-volt loads fed from the station service buses.

4.2.2 Undervoltage

The offsite grid voltage at 505 kV, loss of one of the 500/230/36.5 kV autotransformer with auto transfer of the affected 34.5 kV bus to the 230/36.5 kV transformer. Unit 2 experiences a CLS with a Unit 1 trip transferring its station service loads to the RSST's at the same instant the CLS occurs. All Class 1E motors receive an instantaneous start signal with LTC movement.

4.3 ANALYSIS VERIFICATION

VEPCO verified their computerized voltage analyses calculations by performing a voltage profile test. The profile test was conducted during the startup of Unit 1 in which voltage and current measurements were taken on the reserve system. System parameters were monitored from the 500 kV and 230 kV buses down to the 480-volt buses. The measuring of system parameters was accomplished by using strip-chart recorders and the readings from permanent mounted meters. The bus loading conditions on the 4160-volt buses ranged from 11% to 65% of maximum bus load. Inputting the measured parameters into the computer model, a voltage profile was then computed. Comparing the actual measured voltage conditions to the calculated values resulted in a computer model which is highly conservative. The percentage errors ranged from 3.35% to 7.18% on the 4160-volt buses, and from 4.29% to 6.26% on the 480-volt buses with the measured values being higher than the calculated.

TABLE 1

SURRY POWER STATION, UNITS 1 AND 2
CLASS 1E EQUIPMENT VOLTAGE RATINGS AND ANALYZED
WORST CASE BUS VOLTAGES
(in % of Equipment Nominal Voltage Rating)

		Maximum		Minimum		
		Rated	Analyzed(a)	Rated	Analyzed(a)	
Equipment	Nominal Voltage Rating (100 %)		Steady State		Steady State	Transient
Motors						
	4000					
Start				70		83.93
Operate		110	107.4	90	98.28	-
	460					
Start				70		69.70
Operate		110	108.5	90	92.66	
MOV's	460(b)					
Start				80		82.40
Operate		110	108.5	90	92.66	
Starters(c)	120					
Pickup				83	(d)	
Dropout		50				(d)
Operate		110	(d)	90	(d)	
Other(e) Equipment						

(a) Minimum required bus voltages were calculated for the Class 1E loads including all voltage drops in cables to meet the starting and running design voltages (Appendix D, Ref. 4).

(b) Existing Class 1E motor operating valves (MOV's) are rated; 1) 460 volt ± 10% continuous and starting, 2) 440 volt ± 10% continuous, - 15% starting analysis assumes all MOV's will be rerated or replaced with a 460-volt ± 10% continuous, -20% starting rating. The MOV's are modeled as starting loads, drawing locked rotor amps, through the first 5 seconds.

(c) Fusing is not used for primary protection of a Class 1E load or for control transformer protection in Class 1E control circuits.

(d) The licensee has committed to upgrading the control transformers to ensure adequate operation of the MCC contactors under worst case conditions.

(e) 120-volt vital bus loads and instrumentation are fed from either uninterruptable power supplies or from regulating transformers.

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 voltage analyses submitted for minimum grid voltage and maximum load demand conditions resulted in various voltage profiles where the voltage to the 460-volt Class 1E MOV's did not meet the minimum required starting voltage at T = 0 seconds for the conditions analyzed. The analyses assumed that all the MOV's have a 80% of 460-volt starting rating. The worst case analyzed voltage was 4.1% of 480 volts below the required minimum starting voltage. A highly conservative computer model was used to analyze these scenarios. The following conservatisms were used in the model:

(a) Both units tripping with load transferring (with one unit experiencing a CLS) at the same instant that the electrical abnormalities occur is a very improbable event.

(b) All motors upon receiving a CLS or SI were assumed not to be running and to start at T = 0 seconds. Some Class 1E motors are normally running.

(c) Starting loads were modeled at a power factor of 0.0.

(d) A 15 kV drop in the 500 kV voltage to 505 kV was assumed to occur at the same instant of the condition analyzed. This 15 kV drop is 3 kV greater than the maximum expected.

(e) The measured test verification results ranged from 4.29% to 6.26% higher than those calculated on the 480-volt buses.

Therefore, due to these conservatisms, modifications, and plant operating restrictions, adequate voltage within the design voltage ratings will be ensured down to the 480-volt level under the worst case conditions. The licensee has committed to submit the results of the MOV re-rating and/or replacement and the results of the MCC control transformer upgrading with the worst case undervoltage and overvoltage analyses.

(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 voltage analysis shows that the Class 1E equipment's voltage design rating is not exceeded for minimum plant load and maximum expected offsite grid voltage conditions.

(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.

The voltage analyses profiles with instantaneous LTC movement resulted in several scenarios where at T = 7 seconds the voltage on the Class 1E buses may be below the degraded grid protection scheme setpoint. The profiles show that a voltage of 1%-2% below the setpoint could be experienced. For CLS or SI conditions, the setpoint is 90% ± 1% of 4160 volts with a time delay of 7 ± 0.35 seconds. Evaluation of these scenarios with the degree of conservatism in the computer model and the test verification results finds that spurious trips from the offsite source will not occur for these conditions analyzed.

Modifications will be made to block the automatic starting of the condensate, high pressure heater drain, bearing cooling, and component cooling pumps for 315 seconds after the occurence of a CLS or SI. This blocking will prevent spurious separations from occuring should one of these motors start before steady state conditions are reached. Manually starting (non-automatic capability) the reactor or steam generator feedwater pumps could cause spurious separation during a CLS or SI. Caution statements have been incorporated into the plant's emergency procedures to ensure that the operators are aware of the consequences of starting these motors.

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

VEPCO verified their voltage analyses by performing a voltage profile test. The test results proved the computer model to be highly conservative with the percentage errors judged 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 reviewed the plant's electrical power systems and determined that three modifications were necessary to eliminate the possibility of a simultaneous loss of both offsite circuits. The three modifications are as follows [Ref. 4]:

(a) Both disconnects (one on each side) of the 34.5 kV tie breaker which is normally open between the two 34.5 kV buses (5 and 6) will be left open. This will eliminate any possibility due to the tie breaker failure. Operating procedures will be incorporated for this alignment when both the 34.5 kV feeder breakers from the 230/36.5 kV transformer are in the manual operation only because the loss of power to either 34.5 kV bus will cause the automatic closing of the tie breaker.

(b) A modification, not yet determined, will be incorporated to eliminate the possibility of a fire causing the loss of all three RSST control cables from the turbine building to the switchyard.

(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).

Based on the computer model conservatisms, plant modifications and operating capabilities and restrictions, and the test verification resluts, the analyses demonstrate that the shared offsite sources have the capability and capacity to supply adequate voltage to the Class 1E equipment for an SI or CLS in one unit and a safe shutdown of the remaining unit.

6. CONCLUSIONS

Based on the information submitted by VEPCO for the Surry Nuclear Power Station, Units 1 and 2, it is concluded that:

(1) With the re-rating and/or replacement of the MOV's, implementation of an automatic load shedding scheme, adherence to strict plant operating capabilities and restrictions, control circuit modifications and hardware upgrading, the offsite sources in conjunction with the onsite distribution system have the capacity and capability to automatically start and continuously operate the Class 1E equipment (to the 480-volt level) within their design ratings under worst case conditions.

(2) Spurious separations from the offsite sources will not occur as the result of voltage transients caused from the automatic starting of equipment or the manual starting following steady state conditions of the condensate, high pressure heater drain, bearing cooling or component cooling pumps. Caution statements have been incorporated into plant procedures on the starting of the reactor coolant or steam generator feedwater pumps which may cause spurious trips during a CLS or SI.

(3) The computer analyzed voltage profiles were verified by test with the result confirming the model's conservatism.

(4) The sharing of the offsite sources has the capacity and capability to supply adequate voltage to the units' Class 1E equipment for an accident condition in one and a safe shutdown of the remaining unit.

(5) With the incorporation of operating procedures to ensure proper breaker alignment and disconnect positioning (to the open position) on both sides of the 34.5 kV tie breaker and 34.5 kV feeder breakers and with the prevention modification to the RSST control cables will ensure that the simultaneous loss of both required offsite circuits (GDC 17) will not occur.

The licensee has committed to replacing any MOV which cannot be rerated to 80% voltage starting with 80% rated MOV's and to upgrading the MCC control transformers to adequate sizing to ensure adequate contactor operation under worst case conditions. Therefore, I recommend the NRC accept the voltage analyses of the station's electrical distribution system to supply adequate voltage under worst case conditions.

REFERENCES

1. NRC letter (W. Gammill) to all Power Reactor Licensees, dated August 8, 1979.

2. VEPCO letter (B. R. Sylvia) to NRC (S. A. Varga), dated May 26, 1981.

3. VEPCO letter (R. H. Leasburg) to NRC (S. A. Varga), dated December 31, 1981.

4. VEPCO letter (R. H. Leasburg) to NRC (S. A. Varga), dated March 31, 1982.

5. VEPCO letter (R. H. Leasburg) to NRC (S. A. Varga), dated June 11, 1982.

6. VEPCO letter (R. H. Leasburg) to NRC (S. A. Varga), dated June 30, 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."