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TECHNICAL EVALUATION REPORT ON THE ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES FOR THE VERMONT YANKEE NUCLEAR POWER STATION

(Docket No. 50-271)

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ABSTRACT

This report documents the technical evaluation of the adequacy of the station electric distribution system voltages for the Vermont Yankee Nuclear Power Station. 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 evaluation finds that the voltage analyses submitted demonstrates that adequate voltage will be supplied to the Class 1E equipment under worst case conditions.

FOREWORD

This report is supplied as part of the Selected Electrical, Instrumentation, and Control Systems Issues (SEICSI) 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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TECHNICAL EVALUATION REPORT ON THE ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES FOR THE VERMONT YANKEE NUCLEAR POWER STATION

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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 March 17, 1980 [Ref. 2] and December 29, 1980 [Ref. 3], Vermont Yankee Nuclear Power Corporation, the licensee, submitted their analysis of the adequacy of the electrical distribution system's voltages at Vermont Yankee Nuclear Power Station.

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 system to maintain the voltage for the required Class 1E equipment within acceptable limits 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. 4].

(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. 4].

(3) ANSI C84.1-1977, "Voltage Ratings for Electric Power Systems and Equipment" [Ref. 5].

(4) IEEE Std. 308-1974, "Class 1E Power Systems for Nuclear Power Generating Stations" [Ref. 6].

(5) "Guidelines for Voltage Drop Calculations," Enclosure 2, to NRC letter dated August 8, 1979 [Ref. 1].

3. SYSTEM DESCRIPTION

A one-line diagram of Vermont Yankee Nuclear Power Station's electrical distribution system is shown in Figure 1. This figure was adapted from Figures 2.1 through 2.5 of Reference 2. As shown in Figure 1, there are two 4160-volt Class 1E buses and two 480-volt Class 1E buses. During normal plant operation, 4160-volt Class 1E buses 3 and 4 are connected to station auxiliary buses 1 and 2, respectively. Auxiliary buses 1 and 2 are energized by unit auxiliary transformer T-2. The 480-volt Class 1E buses 8 and 9 are energized through station service transformer T-8 and station service transformer T-9, respectively. Upon loss of the main generator, buses 1 and 2 are automatically transferred to start-up transformers (SUT's) T-3A and T-3B, respectively.

The main generator is connected to the 345 kV switchyard through the main transformer T1. There are three lines which are connected to the 345 kV switchyard and one line connected to the 115 kV switchyard from which the startup transformers T-3A and T-3B are supplied. A 345/115 kV autotransformer connects the two switchyards together.

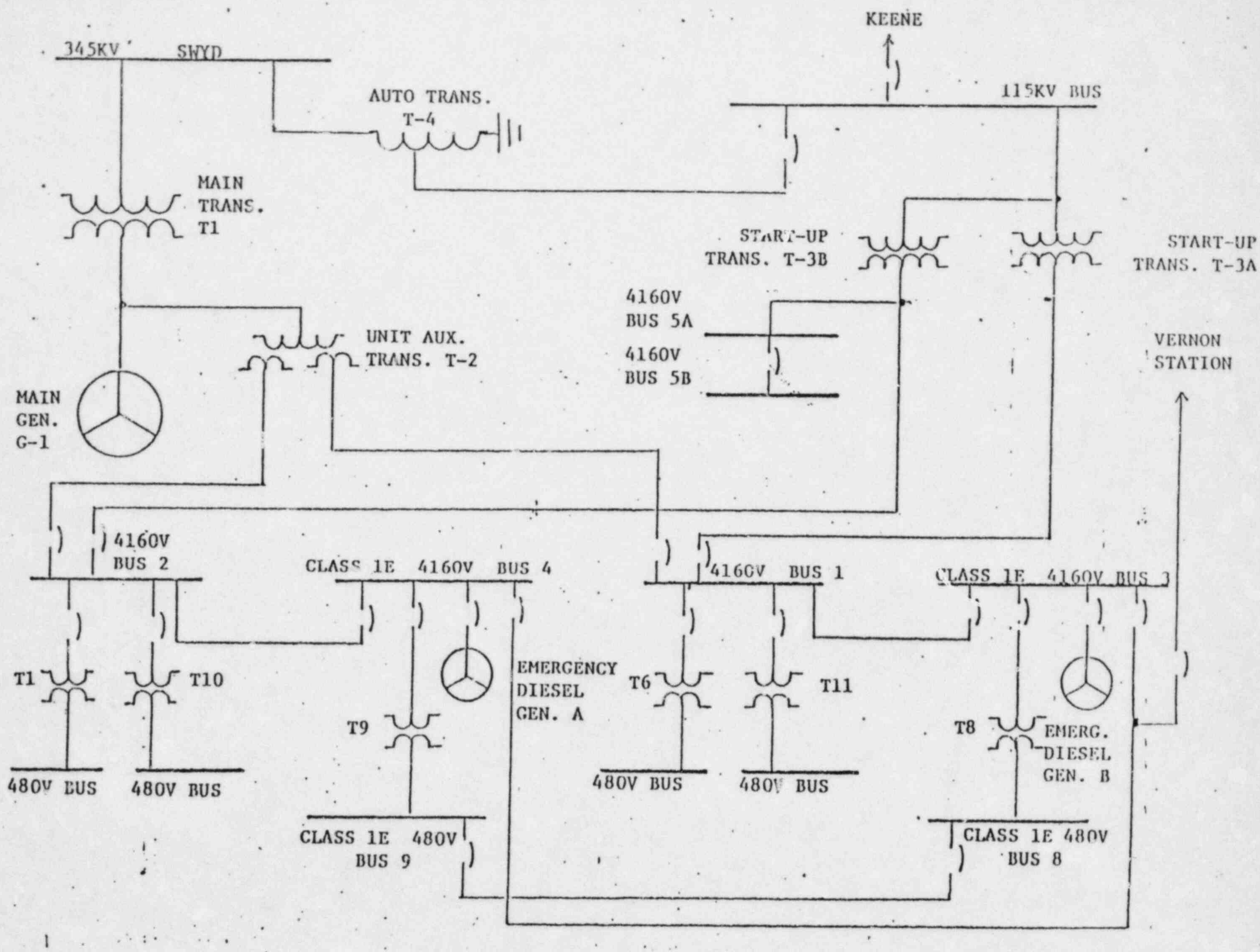

FIGURE 1 VERMONT YANKEE NUCLEAR POWER STATION - ONE-LINE DIAGRAM

Protecting the Class 1E equipment from undervoltage conditions is accomplished by two levels of protection. The first level (loss-of-voltage) scheme which utilizes two relays on each 4160-volt Class 1E bus. The relays (2-out-of-2 logic) will operate in 1.25 seconds at zero voltage, 6.0 seconds at 41% of 4160 volts, and will not operate above 46% voltage. The second level scheme (proposed) also utilizes two relays per 4160-volt Class 1E bus in a 2-out-of-2 logic. These relays will have a setpoint of 3700 volts ± 40 volts (88.9% ± 1% of 4160 volts) with a time delay of 10 seconds ± 1 second.

4. ANALYSIS

4.1 ANALYSIS CONDITIONS

Vermont Yankee Nuclear Power Corporation (VYNPC) analyzed the distribution system voltages using computer load flow programs. Several cases were analyzed to determine worst case transient voltage drops and steady state voltages. These cases evaluated voltages for maximum load/minimum offsite grid voltage, minimum load/maximum offsite grid voltage, and for the effects of starting a large non-Class 1E load for all possible source connections. The minimum and maximum offsite grid voltages used were 340 kV and 362 kV for the 345 kV system and 110 kV and 121 kV for the 115 kV system, respectively. The analyses evaluated conditions of load and no-load transfers from one source to another with safeguard loads starting and steady state voltages following safeguard load starting. In addition to these conditions, several other assumptions were made and are as follows:

(a) The plant was considered to be at normal operation when an accident signal initiated a turbine trip, a transfer of loads, and the start of the emergency loads.

(b) Cable impedence to the terminals of each safety load was calculated. Cable capacitance was neglected.

(c) Transformer nameplate impedences were used.

(d) Motor nameplate values were used.

(e) Load factors were assigned for intermittent loads.

(f) For motor starting, all loads were converted to constant real current and constant imaginary reactance equivalents (all resistive loads are treated as motors).

(g) No load shedding was considered.

In evaluating the starting of a large non-Class 1E load (reactor feed pump), the analysis assumed that two condensate pumps, two circulating water pumps, three circulating water booster pumps, and two recirculating M-G sets

had been shed prior to the motor start. The reactor feed pump will accelerate in 6 seconds at 80% of 4000 volts.

4.2 ANALYSIS RESULTS

The results of the first round analysis required changing taps on startup transformers T-3A and T-3B and the 4160/480-volt station service transformers. This change is necessary when the plant is in a closed cooling cycle mode. The analysis was performed again with the tap changes and resulted in the worst case Class 1E equipment terminal voltages occuring under the following conditions and are presented in Table 1:

4.2.1 Overvoltage

The unit is in a cold shutdown with minimum loads of three station service water pumps, one residual heat removal pump, one RHR service water pump, lighting loads, and various other 480-volt system loads. The grid voltage was 362 kV and 121 kV for the two transmission systems and only one startup transformer in service.

4.2.2 Undervoltage

Unit is in an accident mode with only one startup transformer in service, the startup transformer is carrying the plant's auxiliary loads (no transfer) with simultaneous starting of the Class 1E loads. The grid is at 340 kV and 110 kV for the two switchyard voltage systems A tap change is necessary for single startup transformer operation (112 kV tap for the SUT and 4060 volt tap for the 4160/480 volt-station service transformers). This tap change is a manual operation.

4.3 ANALYSIS VERIFICATION

VYNPC verified their computerized voltage analyses calculations by using the computer load flow program and a model of the auxiliary power system to predict bus voltages for actual plant conditions. Two verification tests were made with the distribution system at 80% of maximum load during steady state conditions. The combined test data resulted in percentage errors of + 1.21% to - 2.95% on the 4160-volt Class 1E buses and of + 1.09% to - 1.73% on the 480-volt Class 1E buses. A negative error percentage indicates that the measured voltages were higher than the calculated.

5. EVALUATION

The NRC generic letter [Ref. 1] stated several requirements that each plant must meet in its voltage analyses. 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

TABLE 1

VERMONT YANKEE NUCLEAR POWER STATION
CLASS 1E EQUIPMENT VOLTAGE RATINGS AND
WORST CASE TERMINAL VOLTAGES
(in % of Equipment Nominal Voltage Rating)

		Maximum Voltage		Minimum Voltage		
		Rated	Analyzed	Rated	Analyzed (a)	
Equipment	Nominal Voltage Rating		Steady State		Steady State	Transient
Motors	4000					
Start				90 (a)		85.3(b)
Operate		110	110.8	90	90.7	
Motors	460					
Start				90		83.9(b)
Operate		110	112.2(c)	90	89.6	
Starters	460					
Pickup				80	84.8	
Dropout		70				83.3(d)
Operate		110	112.2(c)	90	90.2	
Other(e) Equipment	120/240	110	-	85	86.7	83.3

(a) Two 4160-volt Class 1E motors (RHR and core spray pumps) are rated for 80% start voltage.

(b) This voltage is the lowest experienced during the bulk starting of the large 4000-volt RHR and core spray motors. The voltage transient caused from these motors starting lasts on the order of 2-3 seconds. Upon motor acceleration, adequate starting voltage will be supplied to the remaining Class 1E equipment.

(c) Percent voltage is at bus and motor control center (MCC) level.

(d) Lowest transient voltage experienced during start of the largest non-Class 1E motor (reactor feed pump) following steady state conditions of the fully loaded Class 1E buses.

(e) Low voltage AC buses normally supplied from 120/240 volt UPS. Worst case occurs when buses are supplied from their maintenance tie from a MCC.

must be capable of starting and continuously operating all Class 1E equipment within the equipment's voltage ratings.

VYNPC analyzed their onsite distribution system being energized by offsite sources through either two startup transformers, the unit auxiliary transformer, or one startup transformer under worst case conditions. For the above source connections, transformer tap changes are necessary for two conditions. With the plant in a closed cooling cycle mode, tap changes on SUT's T-3A and T-3B and the 4160/480-volt station service transformers is required. For the condition with only one SUT in service, the taps on the remaining SUT will be changed to the 112 kV tap and the 4160/480-volt service station transformers to the 4060 volt tap.

The analysis results for worst case conditions indicate that during bulk Class 1E motor starting, adequate starting voltage is available to the RHR and core spray pump motors. The speed and torque curves for these motors show that the voltage transient will last only for 2-3 seconds before reaching operating speed. Following this short 2-3 second voltage dip, the voltage will recover to acceptable levels which ensure adequate starting and operating voltage to the remaining Class 1E equipment.

(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 results show that the voltage could exceed the upper voltage design rating for the 4000-volt motors and the 460-volt motors by 0.8% and 2.2%, respectively. The magnitude of these overvoltages is considered negligible as the effect on the motors will be inconsequential to the life or performance of the motors.

(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 analyses submitted demonstrate that the worst case voltage transients are not of sufficient time duration to cause spurious separations from the offsite sources. However, for worst case steady state conditions, the upper tolerance of the degraded voltage relays is such that spurious separations could occur. Since these setpoints are only proposed, final installation and testing may result in lowering the tolerance band to preclude the possibility of spurious separations. Also, due to the close control of the grid voltage by the plant's operators, experiencing grid voltages near the minimum expected in conjunction with the worst case loading and having both relays drift in the same direction has a low probability of occurring.

(4) Test results are required to verify the voltage analyses calculations submitted. The licensee performed tests which verified that the analysis results submitted 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 with GDC 17).

The licensee states that they have reviewed the electric power system at Vermont Yankee Nuclear Power Station and have found total compliance with GDC-17. They state also that to the extent practical there are no events or conditions which could result in the simultaneous or consequential loss of both required circuits to the offsite network [Ref. 2].

6. CONCLUSIONS

Based on information submitted by VYNPC for the Vermont Yankee Nuclear Power Station, it is concluded that:

(1) The offsite sources (with certain required tap changes) in conjunction with the onsite distribution system have the capability and capacity to automatically start and continuously operate the Class 1E equipment within their design voltage ratings under worst case conditions.

(2) The potential overvoltages are of negligible magnitude to have any adverse effect on the life or operability of the Class 1E motors.

(3) No event or condition will result in the simultaneous or consequential loss of both required circuits to the onsite distribution system.

(4) The voltage analysis was verified by test with the error percentages and judged acceptable.

(5) There will be no spurious separations from the offsite sources due to the low probability of experiencing minimum expected grid voltages with worst case loading in addition to both undervoltage relays drifting to the upper tolerance setpoints.

Accordingly, I recommend that the NRC approve the voltage analysis submitted which shows that the station electric distribution system is adequate to supply acceptable voltages to the Class 1E equipment for the worst-case conditions.

REFERENCES

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

2 Vermont Yankee Nuclear Power Corporation letter (W. F. Conway) to NRC (W. Gammill), dated March 17, 1980.

3. Vermont Yankee Nuclear Power Corporation letter (R. L. Smith) to NRC (T. A. Ippolito), dated December 29, 1980.

4. Code of Federal Regulations, Title 10, Part 50 (10 CFR 50), General Design Criterion 13 and 17 of Appendix A for Nuclear Power Plants.

5. ANSI C84.1-1977, "Voltage Ratings for Electric Power Systems and Equipment."

6. IEEE Standard 308-1974, "Class 1E Power Systems for Nuclear Power Generating Stations."