ABSTRACT

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This report documents the technical evaluation of the proposed design modifications and Technical Specification changes for protection of Class 1E equipment from grid voltage degradation for the San Onofre Nuclear Generating Station, Unit 1. The review criteria are based on several IEEE standards and the Code of Federal Regulations. The evaluation finds that the proposed design modifications and Technical Specification changes will ensure that the Class 1E equipment will be protected from sustained voltage degradation.

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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TECHNICAL EVALUATION REPORT ON THE
PROPOSED DESIGN MODIFICATIONS AND TECHNICAL SPECIFICATION CHANGES
ON GRID VOLTAGE DEGRADATION
FOR THE
SAN ONOFRE NUCLEAR GENERATING STATION, UNIT 1
(Docket No. 50-206)

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1. INTRODUCTION

By letter dated June 3, 1977 [Ref. 1], the U. S. Nuclear Regulatory Commission (NRC) requested the Southern California Edison Company (SCE), the licensee, to assess the susceptibility of the Class 1E electrical equipment to sustained degraded voltage conditions at the offsite power sources and to the interaction between the offsite and onsite emergency power systems at the San Onofre Nuclear Generating Station, Unit 1 (SONGS 1). In addition, the NRC requested that the licensee compare the current design of the emergency power systems at the plant facilities with the NRC staff positions as stated in the June 3, 1977 letter [Ref. 1], and that the licensee propose plant modifications, as necessary, to meet the NRC staff positions, or provide a detailed analysis which shows that the facility design has equivalent capabilities and protective features. Further, the NRC required certain Technical Specifications be incorporated into the facility's operating license.

By letters dated November 4, 1977 [Ref. 2], August 19, 1981 [Ref. 3], December 16, 1981 [Ref. 4], and April 19, 1982 [Ref. 5], the licensee proposed certain design modifications, additions to the Technical Specifications, and limiting conditions of operation (LCO's). The design modifications include the installation of a degraded voltage protection system for the Class 1E equipment. The proposed additions to the Technical Specifications and LCO's are in regard to calibrations, surveillance requirements, test requirements, and "action" statements associated with the proposed voltage protection system.

The purpose of this report is to evaluate the licensee's proposed design modifications, Technical Specification changes, and proposed LCO's to determine that they meet the criteria established by the NRC for the protection of Class 1E equipment from grid voltage degradation.

2. DESIGN BASIS CRITERIA

The design basis criteria that were applied in determining the acceptability of the system modification to protect the Class 1E equipment from degradation of grid voltages are as follows:

- (1) General Design Criterion 17 (GDC 17), "Electric Power Systems," of Appendix A, "General Design Criteria for Nuclear Power Plants," Code of Federal Regulations, Title 10, Part 50 (10 CFR 50) [Ref. 6].
- (2) IEEE Standard 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations" [Ref. 7].
- (3) IEEE Standard 308-1974, "Class 1E Power Systems for Nuclear Power Generating Stations" [Ref. 8].
- (4) NRC staff positions as stated in a letter dated June 3, 1977 [Ref. 1].

3. EVALUATION

3.1 EXISTING UNDERVOLTAGE PROTECTION

The present undervoltage protection system design consists of the following:

- (1) There are two sets of relays on each of the two 4160-volt Class 1E buses 1C and 2C (see Figure 1A of Attachment A*).
- (2) The first of these relays (one relay per 4160-volt bus) is a Westinghouse type CV-6 relay which functions in the event of a loss of offsite power. The relay will isolate the 4160-volt Class 1E buses and shed the loads. The voltage setpoint for this relay is 3675 ± 116 volts (88.34% of 4160 volts). The relay will operate with a time delay as defined by the voltage/time curve in Figure 2, Attachment A.

*Attachment A is a copy of the information submitted in Ref. 5

- (3) The second set of relays are Westinghouse type CV-7 (inverse time) in which there are two per 4160-volt Class 1E bus. For a loss of offsite power alone, these relays provide the appropriate signal to the sequencer to start the diesel generators and trip the reactor. In the event of a loss of offsite power coincident with a loss-of-coolant accident (LOCA), these relays (requires a signal from both 4160-volt buses) will initiate the sequencer to isolate the 4160-volt Class 1E buses, bypass the functions of the CV-6 relay, automatically start the diesel generators, shed loads on the Class 1E buses, close the diesel generator breakers, and perform load sequencing. These relays have a voltage setpoint of 2860 ± 92 volts (69% of 4160 volts). The time delay in relay operation is defined by the voltage/time curve in Figure 2, Attachment A.
- (4) In addition to the undervoltage relays on the 4160-volt Class 1E buses, Westinghouse type CV-7 relays are also located on the 480-volt Class 1E buses. The function of these relays is to protect the equipment on these buses and to automatically start redundant loads on the other buses in the event of a fault or undervoltage condition. Based on the tap value voltage (105 volts) and time dial setting of 7, the relay will operate at $315 \pm 3\%$ volts (68% of 460 volts) with a time delay of $14.5 \pm 5\%$ seconds.

3.2 MODIFICATIONS

The licensee has proposed the following modifications to the existing undervoltage protection scheme (Figure 1B, Attachment A):

- (1) The existing Westinghouse CV-6 relay will be replaced with three CV-6 relays in a two-out-of-three coincident logic. The relays will be set with a time dial setting of 2.4, tap voltage of 110 volts (92.5% of 4160 volts) with a potential transformer (PT) ratio of 4200/120. With these settings, the relay's setpoints are defined by the voltage/time curve shown in Figure 4, Attachment A. The relay operating time tolerance is $\pm 5\%$.
- (2) A third Westinghouse CV-7 relay will be added to the existing two relays and three Westinghouse instantaneous SV relays will be added in parallel with each of the three CV-7 relays. The relays will utilize a two-out-of-three coincident logic. Both sets of relays will be served by the same PT with a ratio of 4200/120. The CV-7 relays will be set with a tap voltage of 93 volts (78% of 4160 volts) and a time dial setting of 1.2. The SV

relays are instantaneous plunger type which are adjusted to 113 volts (95% of 4160 volts). The SV relays will be connected in series with the safety injection signal (SIS) contacts on the sequencer. The CV-7 relay operating voltage/time curve is shown in Figure 4, Attachment A, with a time tolerance of $\pm 5\%$.

With the above modifications, the Class 1E equipment will be protected from degraded voltage and loss of voltage conditions. For sustained voltage degradation below 92.5% of 4160 volts (3848 volts), the CV-6 relays, upon actuation, will initiate the disconnection of the 4160-volt Class 1E buses from the offsite source and shed the loads.

For sustained voltage degradation (loss of power) below 78% of 4160 volts (3245 volts), the CV-7 relays, which are faster acting in the range of 0% to 78% of 4160 volts than the CV-6 relays, will trip the reactor and start the diesel generators. The Class 1E equipment (normally running) will continue to operate until the CV-6 relays actuate to disconnect the buses and shed the loads. At this point in time, the Class 1E buses are not automatically reconnected (energized) nor are the Class 1E loads automatically loaded onto the buses. The operator upon receiving a signal of the conditions will assess the extent of the voltage degradation and either connect the Class 1E buses to the already running diesel generators or to the second offsite source. The loads are then manually connected.

In the event of voltage degradation less than 95% of 4160 volts (3952 volts) and a SIS occurs, the SV relays interlocked with the SIS will initiate instantaneously the disconnection of the offsite source, shed the loads, start the diesel generators and sequentially load the buses. Once the sequencer is initiated, the SV relays will be bypassed to allow the safety injection loads to start without protective tripping due to the starting load voltage transients. The CV-6 and CV-7 relays will be maintained so as to provide continued undervoltage protection.

3.3 DISCUSSION

This section presents a statement on the NRC staff position from their June 3, 1977 letter [Ref. 1] followed by an evaluation of the licensee's design.

3.3.1 NRC Staff Position 1: Second Level of Undervoltage or Overvoltage Protection with a Time Delay

This position is to be met by the licensee meeting certain criteria. Each criterion has been evaluated against the licensee's proposal and is addressed below.

- (1) "The selection of voltage and time setpoints shall be determined from an analysis of the voltage requirements of the safety-related loads at all onsite system distribution levels."

The setpoints of the undervoltage relays (CV-6 and CV-7) are defined by the voltage/time curves in Figure 4 of Attachment A. The CV-6 relays protect the Class 1E equipment from voltage degradation below 92.5% of 4160 volts (3848 volts) with a time delay defined by the curve. The CV-7 relays protect the Class 1E equipment from voltage degradation (loss of voltage) below 78% of 4160 volts (3245 volts) with a time delay defined by its curve in Figure 4, Attachment A. The SV relays interlocked with a SIS will provide instantaneous protection at a degraded voltage below 95% of 4160 volts (3952 volts).

The licensee's analysis shows that these voltage setpoints and time delays will protect all Class 1E motors (Figure 3, Attachment A). Protection is also provided for relays, contactors, fuses, thermal overloads and other Class 1E equipment whose functional performance would be inadequate because of undervoltage.

- (2) "The voltage protection shall include coincidence logic to preclude spurious trips of the offsite power sources."

The proposed modifications incorporate a two-out-of-three coincident logic scheme for the CV-6, CV-7 and SV relays to preclude spurious tripping.

- (3) "The time delay selected shall be based on the following conditions."

- (a) "The allowable time delay, including margin, shall not exceed the maximum time delay that is assumed in the FSAR accident analysis."

The instantaneous tripping of the SV relays interlocked with a SIS will protect the Class 1E equipment from sustained degraded voltage (below 95% of 4160 volts) and insure that all Class 1E equipment will successfully start and be loaded onto the diesel generators within the time assumed in the FSAR accident analysis (29 seconds).

- (b) "The time delay shall minimize the effect of short-duration disturbances from reducing the availability of the offsite power sources."

The time delays associated with the CV-6 and CV-7 relays are long enough to override any short-duration transients.

- (c) "The allowable time duration of a degraded voltage condition at all distribution system levels shall not result in failure of safety systems or components."

The licensee's analysis has shown that the time delays defined by the voltage/time curves for the CV-6 and CV-7 relays will not cause any failure of any equipment connected to and associated with the Class 1E power system.

- (4) "The undervoltage monitors shall automatically initiate the disconnection of offsite power sources whenever the voltage setpoint and time delay limits have been exceeded."

The two-out-of-three coincident logic of the SV relays interlocked with a SIS will automatically disconnect the Class 1E buses from the degraded offsite source and initiate the voltage-storing scheme instantaneously.

The two-out-of-three coincident logic of the CV-6 relays will automatically initiate the disconnection of the Class 1E buses from the degraded source whenever the voltage and time limits (defined by the voltage/time curve) are exceeded. Operator action is then required to manually restore power to the Class 1E buses. A review of operator action will be evaluated by the system evaluation program (SEP) under the Items of V.10B and VII.3, entitled "Systems Required for Safe Shutdown."

- (5) "The voltage monitors shall be designed to satisfy the requirements of IEEE Standard 279-1971."

The licensee states and my review finds that the proposed design modifications will fully comply with the requirements of IEEE 279-1971.

- (6) "The Technical Specifications shall include limiting conditions for operation, surveillance requirements, trip setpoints with minimum and maximum limits, and allowable values for the second-level voltage protection monitors."

Limiting conditions for operation, surveillance requirements and the trip setpoints as defined by the voltage/time curves with tolerances are included in the licensee's proposed Technical Specifications.

3.3.2 NRC Staff Position 2: Interaction of Onsite Power Sources with Load Shed Feature

The second position requires the system be designed to prevent automatic load shedding of the emergency buses once the onsite sources are supplying power to all sequenced loads. If an adequate basis can be provided for retaining the load-shed feature, the licensee must assign maximum and minimum values to the setpoint of the load-shed feature. These setpoints must

be documented in the Technical Specifications. The load-shedding feature must also be reinstated if the onsite source supply breakers are tripped.

The licensee is bypassing the SV relays once the sequencer is initiated by a SIS. This automatic bypassing allows for the safety injection loads to start (producing an 80% voltage dip) without initiating a protective action by the relays. Once the safety injection loads have started, the retention of the CV-6 and CV-7 relays will provide continued undervoltage protection. The licensee has provided adequate basis for retaining this protection. The characteristics of the voltage/time curves (minimum and maximum values) of the CV-6 and CV-7 relays are such that there will be no interaction with the retained protection during the load sequencing onto the onsite sources.

3.3.3 NRC Staff Position 3: Onsite Power Source Testing

The third position requires that certain test requirements be included in the Technical Specifications. These tests are to "...demonstrate the full functional operability and independence of the onsite power sources at least once per 18 months during shutdown." The tests are to simulate loss of offsite power in conjunction with a safety-injection actuation signal and to simulate interruption and subsequent reconnection of onsite power sources. These tests will verify the proper operation of the load-shed system, the load-shed bypass circuitry, and that there is no adverse interaction between the onsite and offsite power sources.

Existing Technical Specifications (4.4, Item 3) include tests to demonstrate the full functional operability and independence of the onsite power sources by simulating loss of offsite power in conjunction with a SIS. The existing loss of power logic to the sequencer (requires a signal from both load groups) allows for no testing provisions for interruption of the onsite sources and automatic subsequent reconnection. Operator action is required to restore system operation on the affected load group while the remaining load group continues operation.

3.4 TECHNICAL SPECIFICATION

The changes proposed by SCE to the San Onofre Nuclear Generating Station, Unit 1 Technical Specifications, reflect the proposed design modifications. Specifically, the proposed changes:

- (1) Include the trip setpoints (voltage/time curves) for the undervoltage protection relays.
- (2) Provide the required coincident logic (two-out-of-three).
- (3) Incorporate action statements regarding limiting conditions for operation when the number of operable channels for undervoltage protection is reduced.

- (4) Provide the surveillance requirements for channel calibration during refueling shutdown and the monthly channel functional test.

4. CONCLUSIONS

Based on the information provided by Southern California Edison Company, it has been determined that the proposed design modifications comply with NRC Staff Position 1. All of the staff's requirements and design basis criteria have been met. The voltage setting and time delays will protect the Class 1E equipment from a sustained degraded voltage condition of the offsite power source.

The licensee is retaining the load-shed feature while the onsite sources are supplying the Class 1E buses, and has submitted in the proposed Technical Specifications the voltage/time curves (minimum and maximum limits) of load-shed feature relay. A review of the setpoint values, limits, and logic circuitry has determined that there will be no adverse interaction of the onsite sources with the load-shed feature during load sequencing, thus the requirements of NRC Staff Position 2 are met.

The proposed additions to the Technical Specifications and the method of testing the logic circuitry have been reviewed and found to meet the requirements of NRC Staff Position 3.

Accordingly, I recommend that the NRC approve the proposed design modifications and proposed Technical Specifications changes.

REFERENCES

1. NRC letter (A. Schwencer) to Southern California Edison Company, dated June 3, 1977.
2. Southern California Edison Company letter (K. P. Baskin) to the NRC (A. Schwencer), dated November 4, 1977.
3. Southern California Edison Company letter (W. C. Moody) to the NRC (D. M. Crutchfield), dated August 19, 1981.
4. Southern California Edison Company letter (K. P. Baskin) to the NRC (D. M. Crutchfield), dated December 16, 1981.
5. Southern California Edison Company letter (K. P. Baskin) to the NRC (D. M. Crutchfield), dated April 19, 1982.
6. Code of Federal Regulations, Title 10, Part 50 (10 CFR 50), General Design Criterion 17 (GDC 17), "Electric Power Systems" of Appendix A "General Design Criteria for Nuclear Power Plants."
7. IEEE Standard 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations."
8. IEEE Standard 308-1974, "Criteria for Class 1E Power Systems for Nuclear Power Generating Stations."

ATTACHMENT A

Figure No.1
SAN DONFRE UNIT 1 4.16 KV BUSES IC-2C
UNDERVOLTAGE AND LOSS OF POWER PROTECTION
LOGIC DIAGRAM

A. EXISTING SCHEME

B. PROPOSED SCHEME

1. Loss of Power
2. Initial Voltage < 95% and SIS

Legend
LOB = Loss of Bus
LOP = Loss of Power
SIS = Safety Injection Signal

ATTACHMENT A

Figure No. 2

EXISTING UNDERVOLTAGE AND LOSS OF POWER PROTECTION

ATTACHMENT A

TIME (SECONDS)

Figure No. 3

SAN ONOFRE UNIT NO.1
4.16-KV BUSES 1C & 2C

SUSTAINED
VOLTAGE DEGRADATION
PROTECTION

Plots of:

1. Typical Induction Motor
Thermal Limit Curve

2. Undervoltage Relay CV-6
Time Curve*

Time Dial Setting : 2.4
PT Ratio : 4200/120

Tap Voltage Setting :

A. Proposed : 110 V

B. Present : 105 V

* Note : Operating Time of CV-6 Relay Tolerance : $\pm 5\%$

ATTACHMENT A

Figure No. 4
PROPOSED UNDERVOLTAGE AND LOSS OF POWER PROTECTION