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April 19, 1982

Director, Office of Nuclear Reactor Regulation
Attention: D. M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
Degraded Grid Voltage
San Onofre Nuclear Generating Station
Unit 1

In connection with the NRC Staff's review of degraded grid voltage, information regarding the conceptual design for the undervoltage protection system at San Onofre Unit 1 has been discussed in several telephone conversations with the NRC Staff. The purpose of this letter is to document that information.

Enclosure 1 provides a description of the conceptual design for the undervoltage protection scheme. As indicated in our letter dated May 1, 1980, implementation of these modifications will be integrated with other plant modifications which may be required as a result of the integrated assessment of the Systematic Evaluation Program. Enclosure 2 provides draft technical specifications for this conceptual design. Following review by the NRC staff and implementation of these modifications, we will submit a formal proposed change to our technical specifications.

If you have any questions regarding this information please let us know.

Very truly yours,

K P Baskin

Enclosure

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ENCLOSURE 1

CONCEPTUAL DESIGN OF SUSTAINED VOLTAGE DEGRADATION PROTECTION SAN ONOFRE UNIT 1

1. BACKGROUND

By letter dated June 3, 1977 (Reference 1), the NRC raised a concern about "sustained voltage degradation" of the offsite power system and requested a second level of protection to prevent the loss of capability of the redundant safety loads, their control circuits, and their associated electrical components. By letter dated November 4, 1977 (Reference 2), SCE identified the two existing sets of undervoltage relays at San Onofre Unit 1, as shown in Figure 1.A. The function of these two sets of relays is as follows:

a. <u>CV-6 relays (One on each of 4.16 kV buses 1C and 2C)</u>

The CV-6 relays function in the event of an undervoltage condition, or loss of voltage condition, to isolate and to shed the loads from the safety related 4.16 kV buses 1C and 2C.

In the event of a loss of voltage condition, the reactor will automatically shut down. In addition, the loss of power will result in loss of the main feedwater pumps which will cause steam generator level to go down. This will automatically start the turbine driven auxiliary feedwater pump, independent of all ac power, to remove decay heat. In addition, a dc emergency thermal barrier cooling pump will automatically start to provide cooling to the reactor coolant pump thermal barriers. Therefore, there is sufficient time for the operator to take the manual actions necessary to restore offsite power or connect the buses of the diesel generators and load other loads onto the buses.

b. <u>CV-7 relays (Two on each of 4.16 kV buses 1C and 2C)</u>

The CV-7 relays function in the event of a loss of offsite power to provide a signal to the sequencer to trip the reactor and start the diesel generators. In the event of a loss of offsite power coincident with a LOCA, these relays will also initiate all sequencer actions necessary to:

1. Trip all the loads.

2. Start the emergency diesel generators.

3. Load all safety related loads sequentially on the diesel generators.

As shown by Figure 2, the CV-6 relays are set with a longer operating time than the CV-7 relays (11.6 sec. versus 1.0 sec. for loss of voltage, for instance). The longer operating time of the CV-6 relay is required for proper coordination with the overcurrent relay protection of the largest motors which have the longest starting time (up to 24 seconds for the 4,000 hp reactor coolant pump motors which are connected to buses 1C and 2C during startup).

SCE also demonstrated in Reference 2 that a sustained voltage degradation was not possible at San Onofre Unit 1. In subsequent correspondence however, (References 3 and 4), SCE agreed to provide a second level of undervoltage protection. As indicated in Reference 4, these modifications will be integrated with other plant modifications which may be required as a result of the integrated assessment of the Systematic Evaluation Program.

This report provides a description of the conceptual design for the undervoltage protection scheme. Section 2 discusses the design conditions associated with sustained voltage degradation that must be satisfied. Section 3 provides a description of the conceptual design and a summary of how this system satisfies those design conditions.

2. SUSTAINED VOLTAGE DEGRADATION CONDITIONS

There are two conditions which are important relative to a postulated sustained voltage degradation. The first involves a voltage degradation under steady state operating conditions. In this case, it is necessary to ensure that electrical components are not damaged by the sustained degraded voltage condition. The second condition involves a degraded voltage in connection with an accident or safety injection signal (SIS). In the latter case, it is necessary to ensure that all safety related components will start and continue to operate satisfactorily to mitigate the accident. These two conditions are discussed in the following paragraphs.

2.1 Steady State Conditions

As indicated by American National Standard C50.41.1977 (Reference 6) electrical motors can operate continuously at rated load at voltages down to 90% of their rated voltage. This limit is based on temperature limitations of the motor insulation. However, below this limit the motors can operate for a considerable period of time without significant degradation as discussed in the following paragraphs.

An undervoltage condition results in higher currents (the current being approximately inversely proportional to the voltage when the voltage does not dip below 80%). These higher currents result in increased copper loss and temperature of the insulation. As determined in References 7 and 8, temperature limits of electrical equipment are based on a loss of life criteria of the insulation. The "rate of insulation deterioration" and the resulting "insulation life" are functions of the temperature with an equation of the type:

$$\log_e \text{(insulation life)} = \frac{B}{T} + \text{constant}$$

T being the absolute temperature, $T = t\ (^{o}C) + 273$

The 90% voltage limit is a long term limit, based on an expected design life of 30 to 40 years. Exceeding this limit does not result in an immediate failure but only in a faster loss of life of the insulation. As shown in Reference 9, Figure 2 on page 801 shows curves (time limits - versus stator current) for several types of induction motors. Although they differ for severe overcurrent (or undervoltage) conditions, beyond ten minutes, they all tend to an asymptote corresponding to the design limit of 90% voltage (or 111% current).

Using the method described in Reference 10, a Motor Thermal Limit Curve was derived as shown in Figure 3. This curve is typical for induction motors and is therefore applicable to all motors at San Onofre Unit 1. Although the actual curves of each individual motor may differ somewhat, in the range of 80% to 90% voltage this is only a minor difference as indicated in Reference 9.

Typical values from Figure 3 are shown in the table below. The limit shown for 90% of rated voltage is a practical value (with a 0.5% accuracy) - theoretically this value is the design motor life (30 to 40 years).

Percent of Rated Voltage	Time Limit (Seconds)
70	75
80	220
85	510
90	>3500

2.2 Safety Injection Signal

If there is a Safety Injection Signal (SIS) present, the minimum acceptable voltage prior to the SIS condition is considered to be 95% of 4160 volts (3952 volts). This limit was based on the following:

a. In the event of an SIS signal, the startup of the safety injection loads should not result in voltages below 80% of any motor voltage rating in the auxiliary system, as shown below:

Auxiliary Bus	Motor Voltage Ratings 100%	80% Limit	Auxiliary Bus Minimum Voltage
4.16-kV Buses	4,160-V	3,328-V	3,328-V
480-V Buses	460-V	368-V	368-V
	440-V	352-V	

b. Voltage studies indicate that the startup of the safety injection loads results in maximum voltage dips of 15.2% on the 4.16-kV buses, and 21.4% on the 480-V buses.

   Using these values, the above auxiliary bus minimum voltages, and the 4.16/0.48-kV tap settings of the service transformers, it can be found that the minimum allowable voltage on the 4.16-kV buses prior to SIS is about 95% of the 4,160 volt nominal rating or 3,952 volts.

Therefore, if the voltage prior to an SIS is less than 95% of rated voltage, this undervoltage condition is equivalent to a Loss of Power condition (LOP). SIS becomes a SISLOP. Because the safety injection system has to be in full operation within 29 seconds, the SISLOP sequence should be in operation immediately.

2.3 Undervoltage Protection During Operation of the Diesel Generators

When the auxiliary system is served by the emergency diesel generators as a result of a Loss of Power (LOP) signal or a combination of Safety Injection Signal and Loss of Power (SISLOP) signal, the undervoltage relays are not bypassed, for the following reasons:

a. During operation of the emergency diesel generators undervoltage conditions or loss of voltage may result from either a fault in the auxiliary system or a problem on the emergency diesel generators. Protection against faults in the auxiliary system is provided by overcurrent relays which isolate the faults by opening the appropriate breakers. Protection against problems in the diesel generators is provided to some extent by relays which open the generator breakers on generator differential. No low voltage or underfrequency conditon can result from excessive loads, because the capacity of the generators was designed to exceed the maximum expected load. In addition, problems in one diesel generator would only affect one train of safety loads.

b. After tripping, an emergency diesel generator is reconnected manually after the cause of tripping has been identified and corrected. The loads are then reconnected manually to the emergency diesel generator.

c. Based on a voltage study of the auxiliary system, the CV-6 relays are not expected to trip during operation of the emergency diesel generators. Their voltage and time delay settings are adequate to prevent spurious trip during transients or during the sequenced startup of the safety injection loads, (which would cause the worst voltage dips).

d. Actuation of the proposed SV relays when the voltage is less than 95% and an SIS signal is initated is very unlikely. The undervoltage condition would have to occur on both 4.16-kV buses 1C and 2C. While this condition is possible when the auxiliary system is served through transformer C because of a sustained voltage degradation on the 220 kV grid, it would be very unlikely to occur on both buses at the same time when each 4.16-kV bus is served independently from its respective 4.16-kV emergency diesel generators.

e. For the same reason as above the CV-7 relays, which are designed to trip the loads and start the emergency diesel generators under loss of power, would not be expected to operate. Loss of voltage protection is provided by the emergency diesel generators protective relays.

3. CONCEPTUAL DESIGN

The conceptual design of the undervoltage protection system for San Onofre Unit 1 is shown in Figure 1.B. The main points of this design are:

a. The existing Westinghouse CV-6 relay will be replaced with three CV-6 relays having the 110-280 range of tap voltage, with the following settings:

Time Dial Setting:	2.4
PT Ratio:	4200/120
Tap Voltage:	110 Volts

The tolerance on the relay operating time is $\pm 5\%$. The time curve of each relay is shown in Figure No. 4.

b. A third Westinghouse CV-7 relay will be added for the loss of power protection, and three Westinghouse instantaneous SV relays will be added in parallel with each of the three CV-7 relays. (Both sets of relays will be served by the same PT with the present ratio of 4200/120.) The tap voltage of the CV-7 relays will be modified from 82 volts (or 69% of 4160 V) to 93 volts (or 78% of 4160 V). The present time dial setting of 1.2 will be maintained. The SV relays are instantaneous plunger type relays with 90 to 98% drop-out to pickup ratio adjusted to 113 V (corresponding to a voltage of 95% of 4160 V). The SV relays will be connected in series with SIS contacts available on the sequencer.

c. Two-out-of-three logic, as shown by Figure 1.B. will be provided for both undervoltage relays CV-6, and loss of voltage relays CV-7 and SV, on each of the 4.16 kV buses 1C and 2C. At the input to the sequencer, two two-out-of three logic modules will be provided for each channel. At any time one channel is removed from service for maintenance, testing, calibration, or replacement, the other two channels will act as one-of-two logic.

This conceptual design will provide undervoltage protection which fully complies with IEEE 279-1971 (Reference 5) including single failure considerations, testing provisions, and indication requirements. The ability of this conceptual design to satisfy the design conditions identified in Section 2 is described in the following paragraphs. Draft technical specifications for this conceptual design are provided in Enclosure 2 to this letter.

3.1 Steady State Conditions

With the current tap voltage setting on the CV-6 relays (see curve B of Figure 3) of 105 volts, corresponding to 88% of the 4160 V rated voltage, the motor thermal limit would be exceeded at about 1,000 seconds. Since such a long sustained voltage degradation is not expected to occur, and since exceeding the limit by only a few percent will only result in a negligible increase of loss of life of the insulation, this is not considered to be an unsafe operation.

However, this protection will be improved by changing the tap voltage setting from 105 to 100 volts which corresponds to 92.5% of the 4.16 kV rated voltage. As shown by curve A in Figure 3, the motor thermal limit will never be exceeded with this setting. The 110 Volt tap voltage setting is not available on the present CV-6 relays, but it can be provided with the 110-280 range type of CV-6 relays as indicated in Reference 11.

These settings of the CV-6 relays will not interfere with the thermal overload protection in the 480-volt motor control centers, fuses, and the proper operation of the control circuits, as discussed in the following paragraphs.

a. A review of all thermal overload protection trip curves in the 480-volt motor control centers was made. As could be expected from typical curves for thermal overload protection, as indicated in Reference 13, these curves follow the motor thermal limits closely and are within a safe margin of the CV-6 relay curves.

b. Fuses are designed for protection against short circuit currents which are much larger than the currents which could be experienced under sustained voltage degradation.

c. Control circuits are connected to the 125 V DC system and the 120 V AC system (through inverters), which are served from batteries. These batteries are unaffected by the postulated AC voltage conditions.

In addition to the CV-6 relays, the CV-7 relays will also act during steady state conditions. As indicated in Figure 2, with the present tap voltage setting of 82 volts, the relay will trip at voltage levels less than 69% of the 4160 volt rating. This setting will be revised to the 93 volt tap voltage setting such that these relays trip at 78% of the 4160 volt rating. The CV-7 relays will therefore act in conjunction with the CV-6 relays. For a postulated sustained voltage degradation to less than 78%, first the CV-7 relays would trip causing the reactor to trip and the diesel generators to start. Other plant loads would continue to operate until the CV-6 relays are tripped. This continued operation will not adversely affect these equipment loads; however, it provides additional time for the operator to assess the situation and either correct the condition or transfer the loads to the diesel generator as appropriate.

In the event of just a loss of offsite power (due either to a loss of power or a sustained voltage degradation) the undervoltage relays will disconnect the buses from the offsite power system, shed the loads and start the diesel generators; however, the buses are not automatically energized nor are the loads automatically connected. The basis for this was discussed in Reference 14.

3.2 Safety Injection Signal

In the event of an SIS, the voltage should be greater than 95% to allow the startup of the safety injection loads. This protection can be provided by an instantaneous relay (plunger type) with a high ratio of drop out to pick up (90 to 98%) such as the Westinghouse SV relay (Reference 12). This relay would be connected in series with an SIS contact, available on the sequencer, to sense the initiation of the SIS condition. These relays would act only in the event of an SIS. Following initiation of the sequencer due to an SIS condition, the SV relay will be bypassed such that the safety injection loads are not tripped due to voltage dips associated with the starting safety injection loads. Once initiated, protection of the safety injection loads from an undervoltage condition will be provided by the CV-7 relays.

Since both CV-7 relays and SV relays result in the same LOP signal in the sequencer, they will be connected in parallel.

4. REFERENCES

1. NRC letter (A. Schwencer) to SCE (J. B. Moore), dated June 3, 1977.

2. SCE letter (K. P. Baskin) to NRC (A. Schwencer), dated November 4, 1977.

3. NRC letter (D. L. Ziemann) to SCE (J. M. Drake), dated July 31, 1979.

4. SCE letter (K. P. Baskin) to NRC (D. L. Ziemann), dated May 1, 1980.

5. IEEE Standard 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations".

6. American National Standard - Polyphase inducation motors for power generating stations C50.41.1977.

7. IEEE General Principles for Temperature Limits in the rating of Electric Equipment - Standard 1.

8. "Electrical Insulation Deterioration Treated as a Chemical Rate Phenomenon" by Thomas W. Dankin, AIEE - Paper 48-19, 1948 Volume 67, Pages 113 through 122.

9. "Induction Motor Temperture Characteristics" by J. F. Heidbreder, AIEE Paper 55-761, 1958 Volume 77, Pages 800 through 804.

10. "Capabilities of Power Plant Motors Under Abnormal Frequency and Voltage Conditions" by G. J. Bonk, H. F. Garbe, and J. J. Heagerty, General Electric Company, Schenectady, N.Y.

11. Type CV Voltage Relay - Instructions - Westinghouse I.L. 41.201H.

12. Type SC, SC-1, SV and SV-1 Relays - Instructions- Westinghouse I.L. 41.766-1C.

13. Square D Company - Product Data - Bulletin M-435, March 1971 Conference Paper Overload Protection of Motors; Four Common Questions

14. SCE letter (W. C. Moody) to NRC (D. M. Crutchfield), dated August 19, 1981.

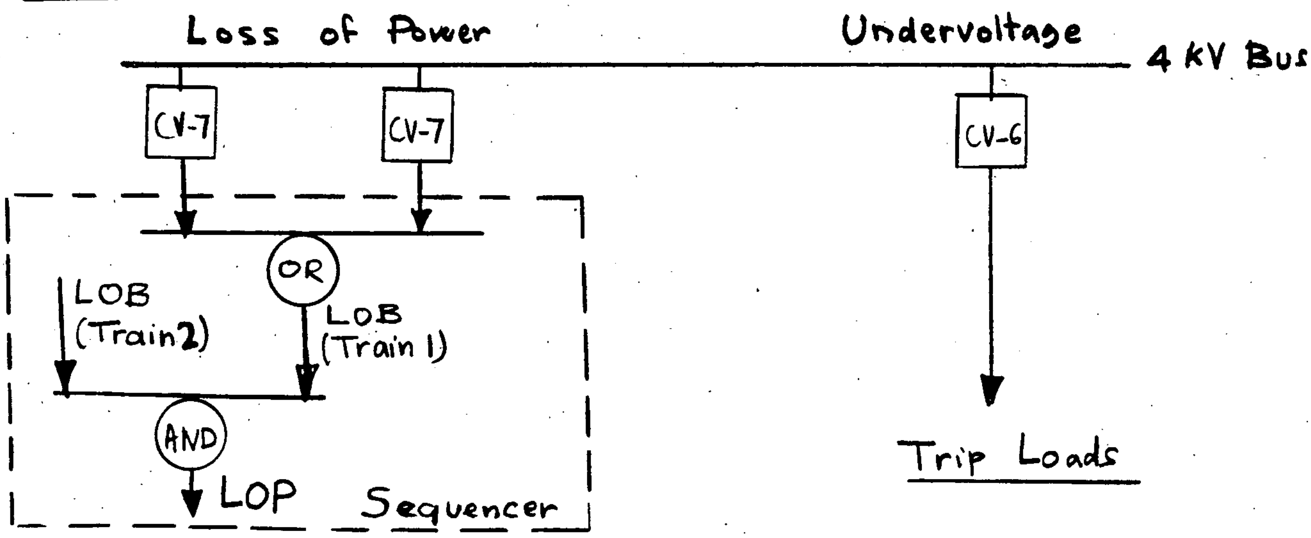
Figure No. 1

SAN ONOFRE UNIT 1 4.16 kV BUSES 1C & 2C

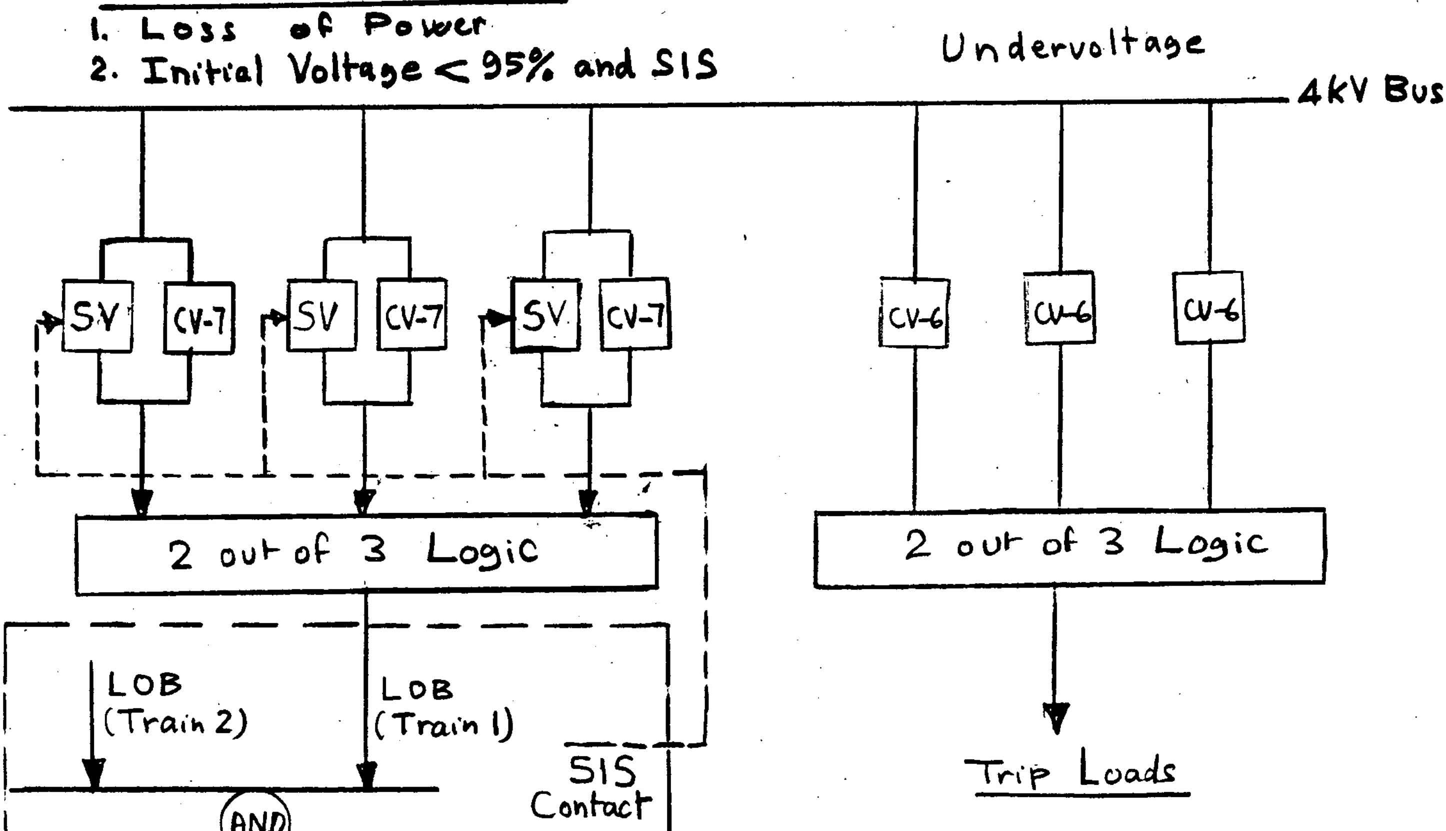
UNDERVOLTAGE AND LOSS OF POWER PROTECTION

LOGIC DIAGRAM

A. EXISTING SCHEME



B. PROPOSED SCHEME



Legend

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

Figure No. 2

EXISTING UNDERVOLTAGE AND LOSS OF POWER PROTECTION

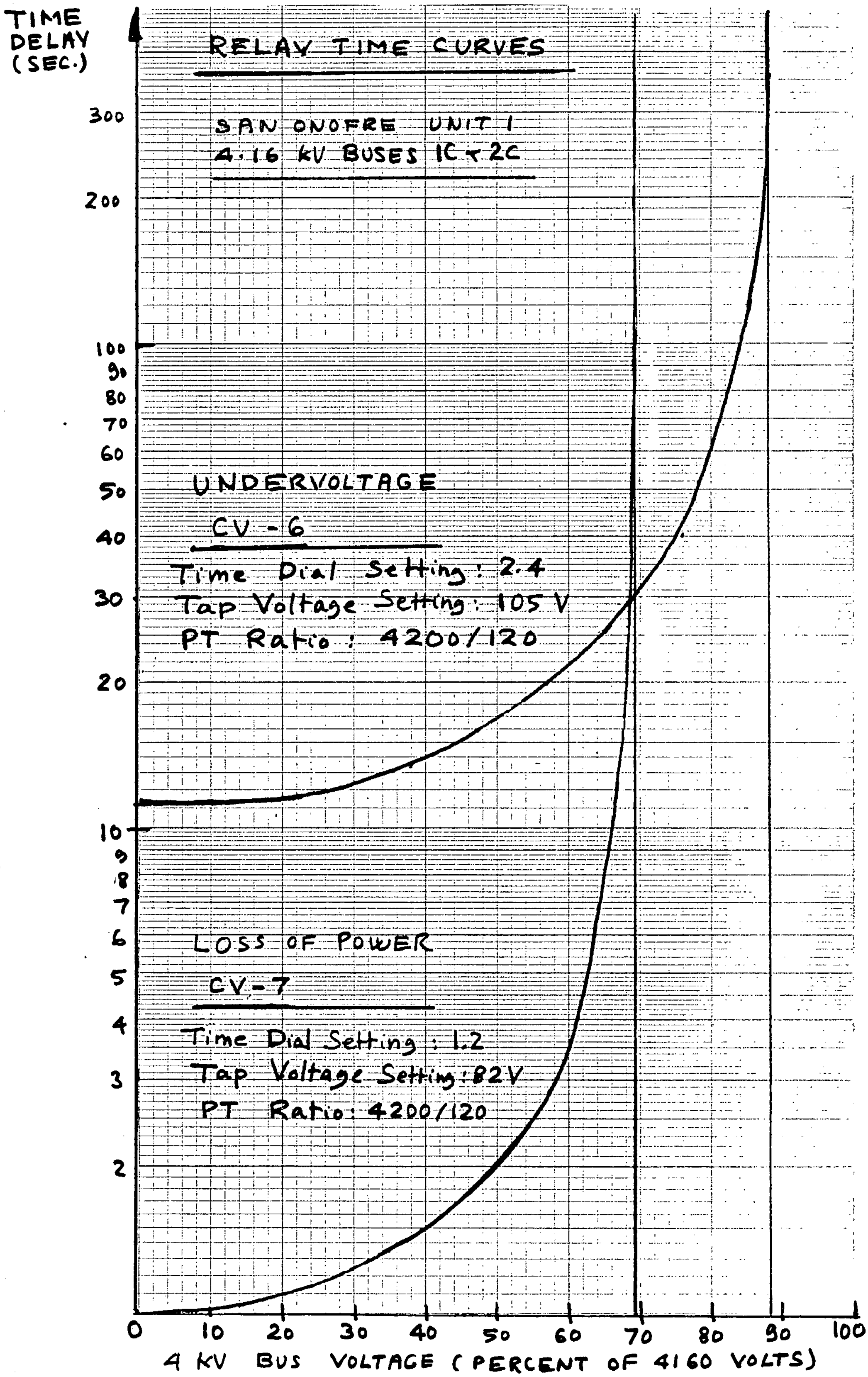
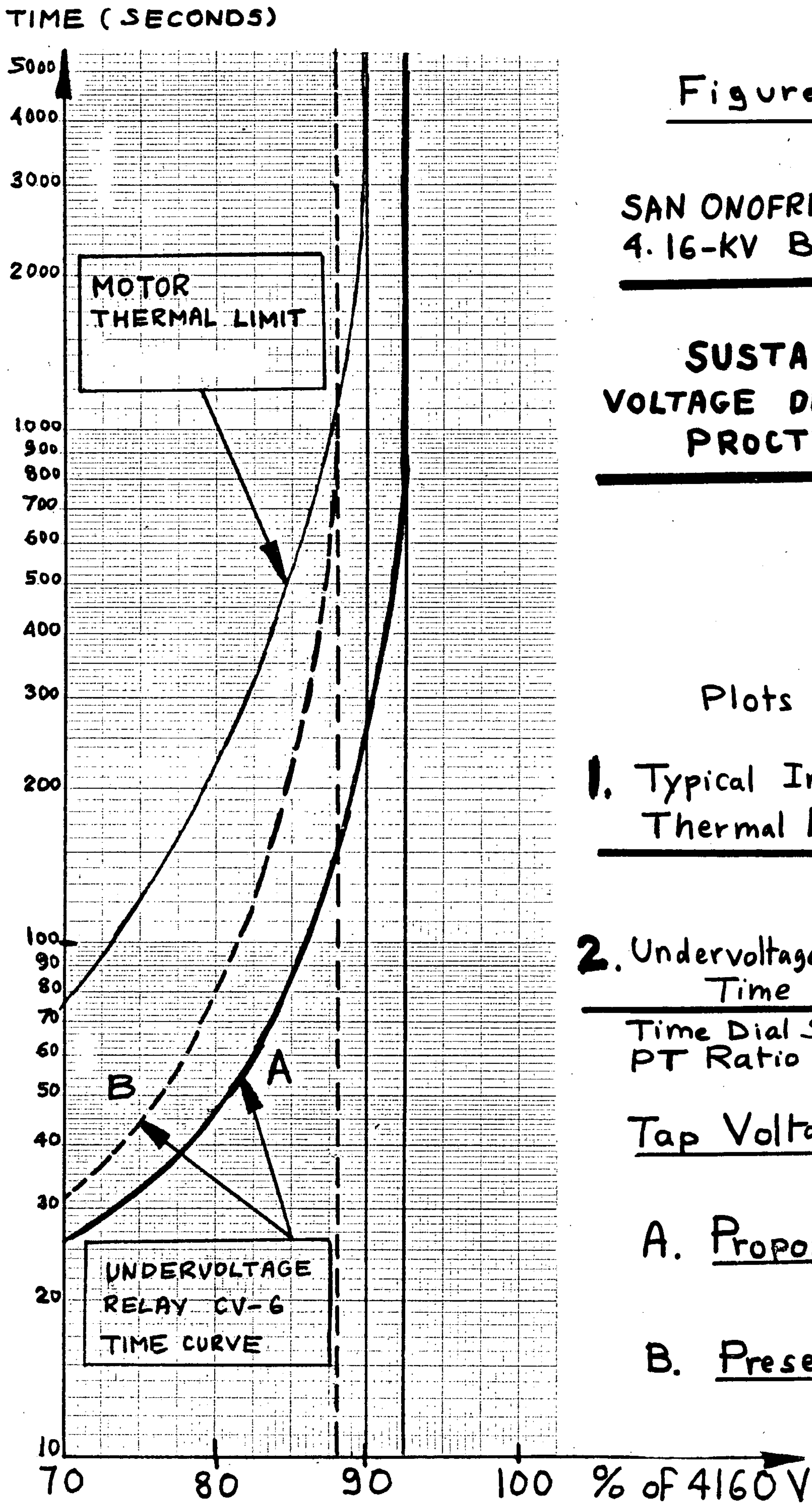


Figure No. 3

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

SUSTAINED VOLTAGE DEGRADATION PROCTECTION



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: ±5%

Figure No. 4

PROPOSED UNDERVOLTAGE AND LOSS OF POWER PROTECTION