Attachment H

(Calculation E4C-130, ICCN C-7)

Proposed Change (218 kV)

SONGS Units 2 and 3

Southern California Edison Company **INTERIM CALCULATION CHANGE NOTICE (ICCN)/ CALCULATION CHANGE NOTICE (CCN) COVER PAGE**	CALC NO. E4C-130	ICCN NO./ PRELIM. CCN NO. C-7	PAGE 1	TOTAL NO. OF PAGES 48
SUMMARY CHANGE ☒ NO ☐ YES	BASE CALC. REV. 1 / UNIT 3	CCN CONVERSION: CCN NO. CCN-		CALC. REV.
	CALCULATION SUBJECT: TLU Calc for Undervoltage Relay Circuits at Class 1E 4 KV Switchgear			
CALCULATION CROSS-INDEX ☒ New/Updated Index Included ☐ Existing Index Is Complete	ENGINEERING SYSTEM NUMBER/PRIMARY STATION SYSTEM DESIGNATOR 1804 / PBA		Q-CLASS II	
Site Programs / Procedure Impact? ☐ NO ☒ YES, AR No. ECP050500255-38	CONTROLLED PROGRAM OR DATABASE ACCORDING TO SO123-XXIV-5.1 ☐ PROGRAM ☐ DATABASE	PROGRAM/DATABASE NAME(S) ☐ ALSO, LISTED BELOW N/A	VERSION/RELEASE NO.(S)	
10CFR50.59/72.48 Review: AR No. N/A (PCN-561)				

1. BRIEF DESCRIPTION OF ICCN/CCN:

This ICCN provides the basis for lowering the DGVS relay setpoints to achieve an acceptable Switchyard voltage of 218 kV as described in AR 0500500255-38. The analysis is performed to determine the settings for the Undervoltage Relays for the 4kV ESF bus 3A04 (127D-1, 2, 3 and 4). Although the analysis applies equally to the other buses, separate ICCN's have been written for each of the 4kV ESF bus of each unit.

This is an entire document ICCN. Changes to the previous revision have been marked by a revision bar in the right margin.

INITIATING DOCUMENT (ECP, OTHER) ECP 050500255 – 38 Rev. 0

2. OTHER AFFECTED DOCUMENTS (CHECK AS APPLICABLE FOR CCN ONLY);
☐ YES ☒ NO OTHER AFFECTED DOCUMENTS EXIST AND ARE IDENTIFIED ON ATTACHED FORM 26-503.

3. APPROVED BY:

C. B. Whittle / 5-26-05 [signature]
ORIGINATOR (Print name/sign/date)
Approval requires PQS T3EN64 Qualification Verified: [initial] Initial

Joshua Park / 5-26-05 [signature]
IRE (Print name/sign/date)
Approval requires PQS T3EN64 Qualification Verified: [initial] Initial

DISCIPLINE / ESC: Electrical / DEO
[signature] 5/26/05
FLS (Signature/date)
Approval requires PQS T3EN64 Qualification Verified: [initial] Initial

4. CONVERSION TO CCN DATE ____________

SCE CDM-SONGS

CALCULATION CROSS-INDEX

ICCN NO./ PRELIM. CCN NO.	C-7	PAGE 2 OF 48
CCN CONVERSION: CCN NO.	CCN--	

Calculation No. E4C-130 Sheet 2 of 48

Calc. rev. number and responsible FLS initials and date	INPUTS: These interfacing calculations and/or documents provide input to the subject calculation, and if revised may require revision of the subject calculation. Calc / Document No.	Rev. No.	OUTPUTS: Results and conclusion of the subject calculation are used in these interfacing calculations and/or documents. Calc / Document No.	Rev. No.	Does the output interface calc/document require Change? YES / NO	Identify output interface calc/document CCN, ECP, TCN/Rev., or tracking number.
Rev. 1 *ICCN C-7* [signature] 5/26/05	E4C-090 CCN 116, *ICCNs C-132, C-133, C-134, C-135*	3	E4C-090	3	Yes	*ICCNs C-132, C-133, C-134, C-135*
	M-0073-061 ICCN C-12	4	E4C-082	2	Yes	*ICCNs C-49, C-50, C-51 & C-52*
			E4C-098	3	Yes	AR 050500255-28
	DBD-SO23-TR-EQ	7	DBD-SO23-120	5	Yes	ECPs *050500255—36, 37, 38 & 39*
	DBD-SO23-140	5				
	SO23-302-2-518	0	SO2-II-11.1A-2	4	Yes	*ECPs 050500255—36, 37, 38 & 39*
	CPD-302-3-35 Sheet C	0				
	SO23-302-2-353	0	SO2-II-11.1B-2	4	Yes	*ECPs 050500255—36, 37, 38 & 39*
	1814-AR286-M0008	0				
	SO123-306-6-16	0	SO3-II-11.1A-2	4	Yes	*ECPs 050500255—36, 37, 38 & 39*
	1814-AU519-M0003	0				
	90042	10	SO3-II-11.1B-2	5	Yes	*ECPs 050500255—36, 37, 38 & 39*
	JS-123-103C	4				
	30220-1	12				
	32220-1	10	UFSAR Section 8.3.1.1.3.13	21	Yes	*ECPs 050500255—36, 37, 38 & 39*
	30230-1	14				
	32230-1	9				
	31468	9				
			J-ZZZ-069	0	Yes	AR 050500255-97

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

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1 PURPOSE

1.1 Purpose

The purpose of this calculation is to perform an analysis associated with the Undervoltage (UV) Relays used for Degraded Voltage Protection in the 4kV Switchgears 2A04, 2A06, 3A04, and 3A06. The following analyses are performed for these relays:

A. Determine the Total Loop Uncertainty (TLU) and Allowable Value Tolerance (AVT),
B. Determine the Nominal UV Relay Pickup (PU) and Dropout (DO) Setpoints,
C. Determine the As-Found and As-Left *acceptance* for the PU and DO,
D. *Determine the New* Technical Specifications *Allowable Values*,
E. *Verify that the PU and DO Setpoints protect the Analysis Limits at the 4kV level.*

This calculation supercedes the portions of E4C-098 (Reference 6.1.2) that determine the settings for the 127D undervoltage relay PU and DO setpoints. The time delay calculations for these relays remain in E4C-098.

Revision 1 to this calculation was issued to incorporate comments provided by an independent third party review. The Undervoltage Relay setpoints are the same as Revision 0. The methodology was revised to include Potential Transformer (PT) uncertainties other than burden and to account for the voltage drop from the PT to the Undervoltage Relays. The resulting TLU is within 0.01% of calculated in the Revision 0 TLU and a positive margin has been maintained with respect to the Analysis Limits. The UV Relays will be evaluated for inclusion in the Out-Of-Tolerance Notification program.

1.1.1 Background

In the mid-1990's, Southern California Edison installed a degraded voltage protection system to ensure San Onofre Nuclear Generating Station (SONGS) separates from offsite power if voltage degrades and remains below the voltage needed to support equipment operability (218 kV). This system could cause SONGS to separate from the preferred and alternate preferred power source(s) if the voltage from offsite sources is between 218 kV and 222.2 kV. When in that voltage band, SONGS could transfer to the standby power source (emergency diesel generators) even though the offsite power remained capable of performing its intended safety function. See SONGS Licensee Event Report No. 2005-003 (Reference 6.6.2) for specific details.

Engineering is continuing to evaluate ways to reduce the voltage required at the SONGS switchyard from 222.2 kV to a lower value. This calculation is intended to support this effort by determining optimal settings for the Undervoltage Relays, *in support of change number PCN-561, to the SONGS Technical Specifications*

1.1.2 Approach

It has been determined that, due to the unique requirements of the settings involved with these relays, the calculation of TLU and setpoints of these Relays will be within the scope the Methodology of JS-123-103C (Reference 6.3.7).

This calculation seeks to minimize the possibility of unnecessarily dropping the 1E Buses from the grid on low voltage. In order to achieve this goal the following approach will be taken.

1.) The calculation of the TLU will be refined to eliminate unnecessary conservatism (compared to the previous calculation, reference 6.1.2), while adhering to SONGS standard JS-123-103C (Reference 6.3.7).

2.) The Dropout Setpoints will be calculated by applying the *SONGS standard methodology for determining setpoints to the Lower (DO) Analysis Limits determined in electrical calculation E4C-090 (Reference* 6.1.3*). The* Allowable Value Tolerance (AVT) *will be applied to determine a NEW DO* minimum *allowable* voltage *which will require a change to* SONGS Technical Specifications (Reference 6.3.2). The results will be consistent with the SONGS standard methodology and includes conservatism (margin).

3.) The Pickup Setpoints will be determined by applying a fixed deadband (the difference between the relay pickup and dropout) to the Dropout Setpoint. These results will be consistent with the standard methodology. *The Allowable Value Tolerance (AVT) will be applied to determine a NEW PU maximum allowable voltage which will require a change to the SONGS Technical Specifications (Reference* 6.3.2*). The PU Setpoint will be shown to be conservative with respect to the Upper Analysis (PU) determined in electrical calculation E4C-090 (Reference* 6.1.3*) and the Margin will be defined with respect to this Analysis Limit.*

1.2 Degree of Accuracy

The results of the TLU portion of this calculation are based on statistical methods in accordance with SCE Engineering Standard for Instrument Setpoint/Loop Accuracy Calculation Methodology, JS-123-103C (Reference 6.3.7). A 95% probability at 95% confidence level as endorsed by RG 1.105 (Reference 6.2.1) is used. Uncertainties are calculated to the nearest 0.001%. Uncertainties and effects which are less than 0.001% will be deemed negligible for purposes of this calculation (see assumption 3.1.11).

The results of this calculation are valid under the assumptions specified in Section 3.0.

1.3 Margin of Safety

The margin of safety is established by two primary sources of conservatism included in this calculation. They are the Miscellaneous Allowance (see Section 3.1.10) and the calculated Margin (see Table 2.1.4). An additional area of conservatism is the application of a ±10 % uncertainty to the calculated burden, used for the Ratio Correction Factor (RCF) uncertainty calculation, as described in assumption 3.1.12.

2 RESULTS/CONCLUSIONS & REQUIREMENTS

2.1 Results/Conclusions

2.1.1 The TLU and AVT associated with the setpoints for Degraded Voltage Function (127D-1, 2, 3, & 4 relays - ABB 27N relay). The following voltages are at the Under Voltage (UV) Relay:

Table 2.1.1

127D Relays	TLU	Allowable Value Tolerance	Location
2A0421 127D-1, 2, 3, 4 2A0617 127D-1, 2, 3, 4 3A0420 127D-1, 2, 3, 4 3A0617 127D-1, 2, 3, 4	±0.48 Vac (±0.4 %)	±0.16 Vac (±0.*132*%)	ESF SWGR room

2.1.2 Pickup and Dropout Setpoints and Acceptance criteria to be used in Surveillance Test Procedures for the 127D Undervoltage (UV) Relays used for Degraded Voltage Detection. These voltages are at the UV Relay:

Table 2.1.2

127D Relays	Setpoint	As-Found Acceptance Band (±0.16 Vac)	As-Left Acceptance Band (±0.10 Vac)
Dropout	*118.13* Vac	*117.97* to *118.29* Vac	*118.03* to *118.23* Vac
Pickup	*118.43* Vac	*118.27* to *118.59* Vac	*118.33* to *118.53* Vac

2.1.3 Calculated Allowable Values *and Revised* Current Technical Specification Allowable Values

Table 2.1.3 provides the calculated allowable values from section 8.5.1, the current *and Revised* Technical Specification Allowable Values at the 4 kV Bus Level.

Table 2.1.3

127D Relays 2A0421 127D-1, 2, 3, 4 2A0617 127D-1, 2, 3, 4 3A0420 127D-1, 2, 3, 4 3A0617 127D-1, 2, 3, 4	Calculated Allowable Values (Section 8.5.1)	Technical Specification Allowable (Section 4.7)	*Revised Technical Specification*
Maximum AV PU	*4144.6*	≤ 4281 V	*≤ 4144.6 V*
Minimum AV DO	*4123.0*	≥ 4196 V	*≥ 4123.0 V*

2.1.4 DO Setpoint, TLU, Margin and Analysis Limits at the 4kV level.

Table 2.1.4 demonstrates that the calculated *PU and* DO setpoints protect *both the Upper and Lower* Analysis Limits, with a positive margin at the 4kV Level.

Table 2.1.4

Relay	Setpoint	TLU	Margin	Analysis Limit
Pickup	*4139.1*	*±16.5*	*5.4*	*4161*
Dropout	*4128.5*	*±16.5*	*6.0*	*4106*

Note: All values are in Vac.

2.1.5 Maximum and Minimum PU and DO Voltages.

Table 2.1.5

Relay	4 kV Level	UV Relay Level
Maximum PU (Nominal PU + TLU)	*4155.9*	*118.91*
Maximum DO (Nominal DO + TLU)	*4145.4*	*118.61*
Nominal PU	*4139.1*	*118.43*
Nominal DO	*4128.5*	*118.13*
Minimum PU (Nominal PU - TLU)	*4122.3*	*117.95*
Minimum DO (Nominal DO - TLU)	*4111.8*	*117.65*

Note: All values are in Vac. Numbers do not exactly match table 2.1.4 due to conservative rounding of results.

2.2 Requirements

2.2.1 Revise Degraded Voltage System Surveillance Procedures (Reference 6.3.8, and any others affected; Maintenance to identify.) as follows:

a.) Revise the allowable as-found and as-left values of the Undervoltage Relays 2A0421 127D-1, 2, 3, 4; 2A0617 127D-1, 2, 3, 4; 3A0420 127D-1, 2, 3, 4; and 3A0617 127D-1, 2, 3, 4 to the values contained in Table 2.1.2 above. (The existing setting tolerance of ± 0.1 Vac remains the same).

b.) Revise the test equipment requirements to require the use of M&TE for calibration which meets or exceeds the following specifications:

1. Range is sufficient to measure the DO and PU setpoints (~120 Vac 60Hz).
2. Accuracy is ±0.057% or better with a 120 Vac 60Hz input.
3. Temperature Effect does not to exceed 0.01% over calibration temperature range (the calculation assumes a calibration temperature range of ± 9F° per Assumption 3.1.3).
4. Resolution is 100 μVac or better.

An Agilent (HP) 3458A Multimeter may be used, under the following conditions:

1. An Auto-calibration (ACAL) must be performed before use and after a 4 hour warm-up (meter power on) period.
2. All readings to be taken within ±9 F° of the ambient temperature at which the ACAL was performed.
3. Synchronous Sub-sample Mode.
4. Use the 100 or 1000 Vac Range.

c.) Revise surveillances to require that the calibration room temperature be recorded.

The implementation of this requirement will be tracked by *ECPs 050500255- 36, 37, 38 & 39.*

2.2.2 Increased Frequency of Relay Setpoint Checks

In order to validate Assumptions 3.2.1 and 3.2.2 "As-Found" data for the relay Dropout and Pickup values must be taken after one month of operation at the new setpoints. All data taken will be forwarded to engineering for analysis. If any allowable values are exceeded during this interval, then Engineering will evaluate the assumption and calibration methodology. Otherwise, Engineering will determine from the data collected, if the assumptions and calibration methodology are correct and determine a new calibration interval for these relays.

The implementation of this requirement will be tracked by ECP 050301091-43,44,45& 46.

2.2.3 Revise Calculation E4C-098

Calculation E4C-098 (Reference 6.1.2) is to be revised to eliminate duplication of this Calculation's settings for the 127D Undervoltage Relays.

The implementation of this requirement will be tracked by AR 050500255-28.

2.2.4 Update the DBD

DBD-SO23-120 (Reference 6.3.4) must be evaluated for changes due to this calculation.

The implementation of this requirement will be tracked by *ECPs 050500255- 36, 37, 38 & 39.*

2.2.5 Update the UFSAR

UFSAR (Reference 6.3.3) must be evaluated for changes due to this calculation. It is already known that section 8.3.1.1.3.13 Electric Circuit Protection Systems item B, Undervoltage Relaying, gives the undervoltage relay setpoint as 4228V at the 4kV bus. This calculation will lower this value (see Table 2.1.4).

The implementation of this requirement will be tracked by *ECPs 050500255- 36, 37, 38 & 39.*

2.2.6 Evaluate the UV Relays for Inclusion in the Out-Of-Tolerance Notification Program

The Relays will be evaluated for inclusion in the SONGS Out-Of-Tolerance Program (OTN) Calculation J-ZZZ-069 (Reference 6.1.5).

The implementation of this requirement will be tracked by AR assignment 050500255-97.

3 ASSUMPTIONS

3.1 Assumptions Which DO NOT Require Verification

3.1.1 Assumed Setpoint (SP) Value for Percentage of Reading Values

The setting tolerance for the relay is ±0.1 Vac (Reference 3.1.2). In order to perform the calculation in percent of setpoint, without knowing the exact setpoint (this is to be determined by the calc), an estimate of the setpoint values for the trip and reset is required. Therefore for conversion of Vac readings only, the undervoltage relay Pickup (PU) and Dropout (DO) are assumed to be set within ±0.75 volt of *118* Vac. Therefore, *118* Vac will be used for computational purposes for uncertainties which are in percent of reading (or percent of setting). This assumption will result in extremely small errors; for the 0.1 Vac case, -Error = ((0.1/(*118*+0.75)-(0.1/*118*))*100% and +Error = ((0.1/(*118*-0.75)-(0.1/*118*))*100%, which is ±0.00*054*% This is *less than* the 0.001% limit assumed to be negligible (see Assumption 3.1.11).

3.1.2 Relay Setting Tolerance

The setting tolerance, used for adjustment of the undervoltage relay setpoint during calibration, is assumed to be ±0.1 Vac. This value is currently being used in the SONGS test procedures (Reference 6.3.8).

3.1.3 Calibration Temperature

Since the Class 1E SWGR rooms are environmentally controlled with normal & emergency chiller, calibration temperature is assumed to be between 55 and 82 ºF (Section 4.4 normal environmental conditions, not calibrated during a LOCA). This temperature band includes the range of temperatures from Summer to Winter conditions. Since the calibration is assumed to be a relatively short duration event (3 to 4 hours) the temperature is assumed not to vary by more than ± 9 Fº during the calibration, because the room is environmentally controlled.

3.1.4 Humidity Effect

Since the Humidity effect is not specified by the manufacturer, it is assumed to be included in the temperature effect, per JS-123-103C section 6.4.1.2 (Reference 6.3.7).

3.1.5 Pressure Effect

Since the undervoltage loops consist entirely of electrical/ electronic components, the error induced by normal environmental pressure changes is negligible and is therefore not considered in this calculation. There are no additional accident pressure considerations associated with this environment (see Section 4.4).

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
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3.1.6 Radiation Effect (Re)

The ESF SWGR room is a low radiation area during both accident and normal conditions (mild environment; see Section 4.4). Therefore the error induced by normal radiation effects to the Undervoltage Relays and Potential Transformers is assumed to be negligible.

3.1.7 Seismic Effect (Se)

The Undervoltage Relays are seismically qualified devices (see Reference 6.5.1 for the seismic specification). Therefore the Seismic Effect for the Undervoltage Relays is considered negligible.

3.1.8 Test Equipment

Test equipment with an accuracy equal to or better than an Agilent (HP) 3458A Multimeter is to be used for calibration of the undervoltage relays (refer to 4.5 for detailed specifications). This will be implemented by Requirement 2.2.1.b.

3.1.9 Potential Transformer Accuracy

The potential transformers are designed and manufactured per ANSI/IEEE Standard C57.13-1993 Requirements for Instrument Transformers (Reference 6.2.2). This standard specifically clarifies that if the PT is used in relaying, only the RCF needs to be determined, and this may be achieved either experimentally or by computation. For these PT's, this has been accomplished by the manufacturer (see attachment 9.1) and need not be repeated in the field.

This calculation will apply the RCF equation of section 8.1.12 of IEEE standard C57.13-1993 (Reference 6.2.2) with a calculated burden rather than use the maximum accuracy of ±0.3% with an unknown burden. In addition to the uncertainty applied to the burden (see Assumption 3.1.12), an additional independent, random error of 0.05% will be included (via SRSS) for the uncertainties associated with the voltage variations caused by environmental, manufacturing variations and other effects associated with the PT.

The requirement for the PT, for voltage applications, is an accurate Turns Ratio. Periodic calibration of the PT to verify the turn ratio change is not required because there is no identifiable mechanism other than failure of the PT to cause the turn ratio to change.

3.1.10 Miscellaneous Allowance

Per JS-123-103C (Reference 6.3.7), the standard miscellaneous allowance of ±0.5% of span is generally assumed. The standard does however allow the value to be changed "at the Engineer's discretion". Based on the accuracy of the devices involved (primarily the undervoltage relay repeatability) an allowance of ±0.5% would be excessive. Therefore, for purposes of this calculation, a miscellaneous allowance of ±0.1% of reading (equal to the undervoltage relay repeatability) will be used.

3.1.11 Negligible Effects and Values

Uncertainties and effects which are determined to be less than 0.001% (one thousandth of one percent) will be considered negligible and eliminated from consideration.

3.1.12 Accuracy of the PT Calculated Burden

The difference from the average burden for each of the individual PT burdens is less than ± 2% (see Section 8.1.1). In order to ensure that this calculation remains bounding and conservative, the mean calculated burden will be used with an uncertainty of ± 10 % to account for the differences in the individual burdens, manufacturing variations and any other unknown effects.

3.1.13 Environmental Conditions of the 2(3)A04 and 2(3)A06 Cubicles

2(3)A04 and 2(3)A06 Cubicles are located in the Class 1E SWGR rooms, which are environmentally controlled with normal & emergency chiller. The relays are mounted inside of the cubicles and will be at a higher temperature than ambient room temperature, but it is reasonable to assume that the temperature elevation is relatively constant and therefore the difference between the highest and lowest temperatures experienced by the relays will be the same as the difference between the highest and lowest room temperatures.

3.1.14 Synchroscope Switch Position

The Synchroscope is assumed to be used (switched onto the PT as a burden) only when the associated bus (2A04, 2A06, 3A04 and 3A06) is being transferred (synchronized). During a degraded voltage event (when the UV relays drop out), the dead bus is automatically transferred to the diesel generator with no synchronization required. EOI Diesel Generator Failure follow-up actions, which manually connect the EDG to a dead bus if the auto circuitry does not function completely, would also activate the Synchroscope. After the grid is stable, synchronization is required to reconnect the 1E 4kV buses to offsite power, however at this point the grid has been stabilized and the Synchroscope will only be needed for a short duration (on the order of 5 minutes). The Synchroscope is not switched into the circuit when the 4kV bus voltage is near the Undervoltage Relay setpoint, therefore the Synchroscope load is excluded from the PT burden calculations.

3.1.15 Voltage Drop from PT to Undervoltage Relay

This calculation will assume a worst case drop in voltage from the PT to the Undervoltage Relay of 0.02 Vac. This assumption is based on the estimated maximum voltage drop determined in Attachment 9.5. The minimum will be conservatively assumed to be zero (0) Vac at the relay. This uncertainty will be applied as a bias since the voltage drop would be normally constant for a constant load.

3.1.16 Confidence Interval

A confidence of 2-σ is conservatively assumed for all uncertainties used as an input to this calculation unless the confidence interval is provided.

3.1.17 Margin

A margin of 6 Volts, relative to the 4kV bus is used in the determination of the Dropout setpoint. This Margin is based on engineering judgment and was chosen based the value being larger than the Allowable Value Tolerance (see Section 8.3). The Margin for the Pickup Setpoint will be calculated.

3.2 Assumptions Requiring Verification

3.2.1 UV Relay Deadband Adjustment

The manufacturer specified deadband adjustment (difference between the dropout and pickup) for the 127D relays may be set down to 0.5% (see Section 4.2). This calculation assumes that the deadband setting may be adjusted down to 0.3 Vac. This is being done with vendor concurrence (see Attachment 9.3). This assumption will be verified by testing per Requirement 2.2.2.

3.2.2 UV Relay Drift (D)

Drift allowance for the 127D-1, 2, 3, &4 (27N) relays is assumed to be equal to the rated accuracy (repeatability) of ± 0.1 % (See Section 4.2), since the vendor drift value is not available. This assumption will be verified by testing, per Requirement 2.2.2.

4 DESIGN INPUTS

4.1 General

The SONGS Unit 2/3 Safety-Related 4kV System consists of four 4kV Buses. Buses 2A04 and 2A06 are the Unit 2 Train A and Train B Buses, respectively, while 3A04 and 3A06 are the corresponding buses for Unit 3.

Bus 2A04 contains 21 separate cubicles numbered from 2A0401 to 2A0421. Bus 2A06 contains 20 separate cubicles numbered from 2A0601 to 2A0620. Bus 3A04 contains 20 separate cubicles numbered from 3A0401 to 3A0420. Bus 3A06 contains 19 separate cubicles numbered from 3A0601 to 3A0619. The cubicles containing the undervoltage relays are given in the table below.

Function	Location			
	Bus 2A04	Bus 2A06	Bus 3A04	Bus 3A06
Cubicle	21	17	20	17
Undervoltage Relay ID Numbers	2A0421 127D-1, 2, 3, 4	2A0617 127D-1, 2, 3, 4	3A0420 127D-1, 2, 3, 4	3A0617 127D-1, 2, 3, 4

4.2 Relay Data for 27N Undervoltage Relay
(Reference 6.5.1 except as noted)

Device No:	127D-1, 2, 3, 4	(Reference 6.3.1)
Manufacturer:	ABB	(Reference 6.3.1)
Type:	27N	(Reference 6.3.1)
Catalog #:	411T5375-HF	(Reference 6.3.1)
Pickup range:	70-120 V	
Dropout delay:	2-20 seconds	
Reset time:	Less than 2 cycles	
	Control voltage: 100-140 V DC	
Temperature range:	-30 to +70° C	
Burden:	0.5 VA at 120 V	

Repeatability (with Harmonic filter):

a. @ constant temperature & control voltage - ±0.1%
b. For allowable dc control power range (100-140 V) - ±0.1%
c. Temp. Range: 0 to +55° C - ±0.75%
   +10 to +40° C - ±0.4%
   -20 to +70° C - ±1.5%
d. Time delay - ±10% or ±20 milliseconds whichever is greater.

Notes:
1. Deadband: Difference between pickup and dropout can be set as low as ±0.5 %
2. The first three repeatability tolerances should be considered independent and may be cumulative.

4.3 Potential Transformer (PT) Data

For the following data, refer to Reference 6.5.3 and Attachments 9.1 and 9.4:

PT ratio:	35:1	MFR:	General Electric
Model:	JVM-3	Thermal Rating:	750VA
Style:	Old No.: 643X094000		
	New No.: 763X021026 (See Attachment 9.4 for confirmation)		
Accuracy:	0.3 W, X, M, Y, 1.2 Z burden @ 60Hz		

PT Tag Data (Attachment 9.1):

	RCF	Burden	Angle	Power Factor
		VA	Minutes	
No Load	0.9974	0	1	1.00
Y	1.0019	75	-2	0.85

4.4 Environmental Condition Data

FORM 4: ENVIRONMENTAL CONDITIONS DATA SHEET

AREA: CB Area B5 (ESF SWGR room) Mild Environment (Reference 6.3.5.)

Parameter	Data	Reference
Normal Temperature Minimum, °F	55°F	6.1.1
Normal Temperature Maximum, °F	81.7°F	6.1.1
Normal Radiation Value, gamma Rads	< 1.0 E4 Rads	6.3.5
Normal Pressure Minimum, psig	0 psig	6.3.5
Normal Pressure Maximum, psig	0 psig	6.3.5
Accident Temperature Maximum, °F	95°F	6.3.5
Accident Radiation Value, Rads gamma	< 1.0 E4 Rads	6.3.5
Accident Relative Humidity Range % RH	80	6.3.5
Accident Pressure Maximum, psig	0 psig	6.3.5

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

4.5 M&TE Used for Setpoint Measurement and Adjustment
(Reference 6.5.8)
Model: Agilent 3458A Multimeter (Agilent was formerly Hewlett Packard)

Range: 100 Vac range (120 Vac Full Scale)
Mode: Synchronous

Accuracy: ±0.02% of Reading + 0.002 % Range (40Hz to 1kHz)
Temperature Coefficient for reading outside of ± 1 C°, but within ± 5 C° of the last ACAL (See note):
±(0.001% of Reading + 0.0001 % Range)/C°
Resolution: 10 μVac
Full scale: 120 Vac

Range: 1000 Vac range (700 Vac Full Scale)
Mode: Synchronous

Accuracy: ±0.04% of Reading + 0.002 % Range (40Hz to 1kHz)
Temperature Coefficient for reading outside of ± 1 C°, but within ± 5 C° of the last ACAL (See note):
±(0.001% of Reading + 0.0001 % Range)/C°
Resolution: 100 μVac
Full scale: 700 Vac

Note: These specifications rely on an the meter being in a thermally stable environment with the power on for 4 hours prior to the auto-calibration (ACAL).

4.6 125 Vdc Control Power

The 125 Vdc control power to the Undervoltage Relays is maintained within the range of 103 Vdc to 140 Vdc per Reference 6.3.6 page 16.

4.7 Technical Specifications Allowable Values

Section 3.3.7 of the current Technical Specification (Reference 6.3.2) gives the following Allowable Values for the Degraded Voltage function :
Dropout ≥ 4196 V
Pickup ≤ 4281 V

4.8 Analysis Limits *at the 4kV Bus*

The *Lower* Analysis Limit for the Undervoltage Relay *DO is determined in CCN 117 to E4C-090 (Reference* 6.1.3.1*). This voltage level ensures that the loads on the ESF Buses have adequate voltage to perform their safety functions.:*

$AL_{DO\ Lower}$ = *4106* Vac at the 4kV Bus

The Upper Analysis limit for the PU is 4161 maximum voltage per Reference 6.1.3.2. This voltage ensures that the ESF Buses remain on the preferred or alternate preferred power source(s) if they are available. Therefore:

$AL_{PU\ Upper}$ *(Pickup) = 4161 Vac at the 4 kV bus.*

4.9 PT Burdens

4.9.1 Individual Component Burdens

Load Type	Vendors Stated Load	Burden (@120 Vac)	Reference
Undervoltage relays 127D-1, 2, 3, 4	0.5 VA (Solid State)	0.5 + j0 VA	6.5.1
127F1, 2, 3, 4 (CV-2)	2.4 VA @ .29 pf	0.70 + j2.30 VA	6.5.4 (Tap set at 105 Vac per 6.3.1)
127R1, 2, 3, 4 (SVF)	17VA @ 27° Lagging	15.15 + j7.72 VA	6.5.6
Hathaway Digital Fault Recorder (DFR)	50 k Ohms	0.288 + j0 VA	6.5.7 Page I-21
TDV and TDV1	0.2 VA	0.2 + j0 VA	9.2
Synchroscope Circuit	N/A	0 VA	Not in circuit per assumption 3.1.14

4.9.2 Burdens On Each Transformer (2A04, 2A06, 3A04, 3A06):

Transformer	Attached Devices (Burdens)	Reference
Undervoltage Circuit 1 PT a-b	127D-3 127F3 127R3 TDV	6.4.1
Undervoltage Circuit 1 PT b-c	127D-4 127F4 127R4	6.4.1
Undervoltage Circuit 2 PT a-b	127D-1 127F1 127R1 TDV1 DFR	6.4.1
Undervoltage Circuit 2 PT b-c	127D-2 127F2 127R2 (Synchroscope)	6.4.1 (Synchroscope is Not in circuit per assumption 3.1.14)

Note: Circuit 1 refers to the upper circuit on the elementary and circuit 2 is the lower. They are labeled as such on the elementary.

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

5 METHODOLOGY

Overview: This methodology is consistent with the requirements of SONGS JS-123-103C (Reference 6.3.7) for safety system setpoints. This loop consists of only the primary element (the PT) and the Undervoltage Relay. The only error attributed to the primary element is the Primary Element Allowance (PEA).

Due to the unique requirements placed on the setting of the Undervoltage Relays, a different methodology is employed to determine the Dropout from that of the Pickup setpoint.

The Dropout setpoint is *determined based on SONGS JS123-103C Standard Methodology with respect to its Lower Analysis Limit. The Margin is calculated between the DO Upper Analysis and the DO setpoint plus the TLU and the Analysis Limit, in order to prove the value is conservative.*

The calculation of the Pickup setpoint is based strictly on applying the minimum acceptable Deadband to the Dropout setpoint in order to minimize the voltage required to ensure reset of the relays (as discussed above). *The Margin is calculated between the setpoint plus the TLU and the Analysis Limit, in order to prove the value is conservative.*

The minimum and maximum trip (setpoint ±TLU) is calculated for both the Pickup and Dropout. *These values are provided for information only.*

5.1 Calculation of Primary Element Allowance (PEA)

5.1.1 Calculation of the PT Burden

The Transformer burden will be calculated by summing each of the burdens connected to the PT.

5.1.2 Calculation of the PT Accuracy

The only source of error considered for the voltage transformer is the Ratio Correction Factor (RCF), since the ratio of the secondary voltage is the only parameter sensed by the undervoltage relays. Equation 5-1 from IEEE standard C57.13-1993 section 8.1.12 (Reference 6.2.2) provides the RCF for the transformer for a given burden, with measured values of the true ratio and phase angle at zero burden, and one other burden. Manufacturer tag data, along with the calculated burden for the transformer will be used to find the applicable RCF.

Equation 5-1

$$RCF_c = RCF_0 + \left[\frac{B_c}{B_t}\right]\left[(RCF_t - RCF_0)\times\cos(\theta_t - \theta_c) + (\gamma_t - \gamma_0)\times\sin(\theta_t - \theta_c)\right]$$

Where,
B_0 = the zero burden for which RCF and γ are known,
B_t = a burden for which RCF and γ are known,
B_c = the burden for which RCF is to be calculated,
Θ_t and Θ_c = power factor angles of burdens Bt and Bc, respectively (in radians)

RCF_0, RCF_t and RCF_c = transformer ratio correction factors for burdens B_0, B_t, and B_c, respectively,
γ_t, γ_0 = the transformer phase angles, in radians, at burdens B_t and B_0 respectively.

Each transformer burden will be calculated based on connected loads. These burdens will be averaged and then a margin (per Assumption 3.1.12) applied to the average to find the maximum and minimum burden. Based on this a bounding burden will be determined and used for calculating the uncertainty of the RCF due to variation in the burden.

The accuracy of the potential transformer will then be given by determining a bounding (conservative) value for the uncertainty of the RCF, based on the uncertainty in the calculated versus the actual Burden. This uncertainty will be part of the PEA term. Because it cannot be shown to be a random process, this portion of the PEA will be applied as a BIAS in the final TLU calculation and will be designated by the symbol PEA_{Burd}.

An additional independent and random uncertainty will be applied per assumption 3.1.9. This uncertainty will be applied via SRSS in the TLU computation. It will be designated by the symbol PEA_{PT}.

5.1.3 Voltage Drop from the PT to the UV Relay (PEA_{VD}).

Per assumption 3.1.15 a bias will be applied to account for the uncertainty of the Voltage Drop from the PT to the UV Relay, due to the cable resistance. This bias will be designated by the symbol PEA_{VD}.

5.2 Calculation of Undervoltage Relay Total Loop Uncertainty (TLU)

5.2.1 The following uncertainties are considered for inclusion per JS-123-103C (Reference 6.3.7):

a. PEA as outlined above.

b. Device Tolerances (Undervoltage Relay only)

- Drift allowance (D)
- Power supply allowance (PSe)
- Temperature allowance (Te - normal & accident)
- Seismic allowance (Se)
- Radiation allowance (Re)

c. M&TE Tolerance
The following uncertainties will be considered for the M&TE tolerance:

- M&TE accuracy (MTE_A)
- Readability (R)
  Readability is ± least significant digit for digital M&TE
- M&TE temperature effect (MTE_{TE})
- M&TE reference standard (MTE_{RS})
  MTE_{RS} is ±25% of M&TE accuracy per JS-123-103C (Reference 6.3.7).

These uncertainties will be combined utilizing the Square Root of the Sum of the Squares Method.

d. Setting Tolerance (ST) Note: Used in lieu of Accuracy in TLU per JS-123-103C (Reference 6.3.7) Section 6.2.

e. Miscellaneous Allowance (Ma)

5.2.2 Combination of TLU Uncertainties

The Square Root of the Sum of the Squares Method as defined in JS123-103C (Reference 6.3.7) is utilized to combine the independent random uncertainties in the determination of the TLU and the biases (PEA in this case) are added. Therefore:

$$TLU = \pm\sqrt{Te^2 + D^2 + PSe^2 + Se^2 + Re^2 + MTE^2 + ST^2 + Ma^2 + PEA_{PT}^{\ 2}} \pm PEA_{BURD} \pm PEA_{VD}$$

5.3 Calculation of Undervoltage Relay Allowable Value Tolerance (AVT)

The allowable value (AV) will be calculated per JS-123-103C (Reference 6.3.7) section 4.4 from the equation:

$$AVT = \pm\sqrt{D^2 + ST^2 + R^2}$$

Where D is the drift of the undervoltage relay, ST is the setting tolerance of the undervoltage relay and R is the readability of the test equipment.

5.4 Calculation of Undervoltage Relay PU and DO Setpoints

5.4.1 *Undervoltage Relay Dropout Setpoint*

The undervoltage relay dropout setpoint is a decreasing setpoint as defined in JS-123-103C (Reference 6.3.7) section 4.7 and is determined by:

SP (Decreasing) = $AL_L + (+TLU) + M$

Where AL_U *is the upper Analysis Limit (see Section 4.8), M is the margin and (+TLU) is the positive TLU.*

5.4.2 Undervoltage Relay Pickup Setpoint

5.4.2.1 Calculation of Relay Pickup Setpoint SP_{PU}

The Pickup Setpoints will be determined by applying a set deadband (DB = the difference between the relay pickup and dropout) to the Dropout Setpoint (SP_{DO}). Therefore:

$SP_{PU} = SP_{DO} + DB$

5.4.2.2 Determination of Margin of PU Setpoint to the PU Upper Analysis Limit (M_{PU})

The undervoltage relay PU setpoint is a increasing setpoint as defined in JS-123-103C (Reference 6.3.7) section 4.7. Therefore the following equation applies:

SP (Increasing) = $AL_U + (-TLU) - M$

Where AL_U *is the upper Analysis Limit (see Section 4.8), M is the margin and (-TLU) is the negative TLU.*

Since the SP_{PU}, *-TLU and AL are known, the margin can be determined by rearranging this equation and solving for the margin. The Margin is:*

$M_{PU} = AL_{PU} - (SP_{PU} - (-TLU))$

NOTE: A positive or zero margin will meet the requirements and a negative margin does not.

5.5 Calculation of Undervoltage Relay PU and DO As-Found/As-Left Acceptance Bands

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

5.5.1 Calculation of Undervoltage Relay As-Found Acceptance Band

The As-Found Acceptance band will be the trip or reset setpoint ±AV (allowable value).

5.5.2 Calculation of Undervoltage Relay As-Left Acceptance Band

The As-Left Acceptance band will be the trip or reset setpoint ±ST (setting tolerance) .

5.6 Calculation of Minimum and Maximum Relay DO and PU at the 4kV Level

The Minimum and Maximum Relay DO and PU Values are calculated by applying the TLU to the setpoint (SP). This yields the following equations:

Maximum = SP + (+TLU)
Minimum = SP + (-TLU)

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

6 REFERENCES

6.1 SONGS Calculations

6.1.1 M-0073-061 ICCN C-12 – Normal Environmental Conditions for the 4kV Switchgear Protective Relay Setting Calculation.

6.1.2 E4C-098 Rev. 3 – 4kV Switchgear Protective Relay Setting Calculation

6.1.3 E4C-090 Revision 3 – Auxiliary System Voltage Regulation
6.1.3.1 CCN 117 – Sensitivity Study to determine Class 1E Equipment Protection
6.1.3.2 ICCNs C-132- for bus 2A04, C-133 for 2A06, C-134 for 3A04 and C-135 for 3A06.

6.1.4 E4C-082 Revision 2 – System Dynamic Voltages During DBA
6.1.4.1 ICCNs C-49 for bus 2A04, C-50 for 2A06, C-51 for 3A04 and C-52 for 3A06.

6.1.5 J-ZZZ-069 Revision 0 – Out-Of-Tolerance Notification Program (OTN)

6.2 Industry Publication and Standards

6.2.1 NRC Regulatory Guide 1.105 Revision 3 Setpoints For Safety-Related Instrumentation

6.2.2 ANSI/IEEE C57.13-1993 - IEEE Standard Requirement for Instrument Transformers.

6.3 SONGS Documents and Procedures

6.3.1 NCDBMEL Version 03.03.03 – Nuclear Consolidated Database Master Equipment List.

6.3.2 SONGS 2 & 3 Technical Specifications (See TS Section 3.3.7.)

6.3.3 SONGS 2 & 3 UFSAR Revision 21 (Section 8.3.1.1.3.13)

6.3.4 DBD SO23-120, Revision 5 - 6.9KV, 4.16KV & 480V Electrical Systems.

6.3.5 DBD-SO23-TR-EQ, Revision 7 - Environmental Qualification Topical Report

6.3.6 DBD-SO23-140 Revision 5 – Class 1E 125 Vdc System

6.3.7 SCE Standard JS-123-103C Revision 4 - Instrument Setpoint/Loop Accuracy Calculation Methodology

6.3.8 Surveillance Test Procedures for Loss of Voltage (LOVS), Degraded Voltage (SDVS, DGVSS) and Sequencing Relays and Circuits

SO2-II-11.1A-2 Revision 4 - S.R. Unit 2 ESF Train A
SO2-II-11.1B-2 Revision 4 - S.R. Unit 2 ESF Train B

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

SO3-II-11.1A-2 Revision 4 - S.R. Unit 3 ESF Train A
SO3-II-11.1B-2 Revision 5 - S.R. Unit 3 ESF Train B

6.4 Drawings.

6.4.1 Elementary Drawings

	Unit 2				Unit 3		
	No.	Rev.	Drawing		No.	Rev.	Revision
A	30220-1	12	2A04 Bus Metering		32220-1	10	3A04 Bus Metering
B	30220-2	2	2A04 Bus Degraded Voltage Detection		32220-2	2	3A04 Bus Degraded Voltage Detection
C	30230-1	14	2A06 Bus Metering		32230-1	9	3A06 Bus Metering
D	30230-2	2	2A06 Bus Degraded Voltage Detection		32230-2	3	3A06 Bus Degraded Voltage Detection
E	31468	9	Synchronizing Potentials		SAME DWG.		

6.5 Vendor documents

6.5.1 SO23-302-2-518 Revision 0 – Instruction Book for ABB Type 27N High Accuracy Relay

6.5.2 SO23-302-2-512 Revision 0 – Type Test Certificate for ABB 27N Relay

6.5.3 4160 Switchgear Bill of Materials ITE Imperial Corporation
6.5.3.1 SO23-302-2-84 Revision 4
6.5.3.2 SO23-302-2-85 Revision 3
6.5.3.3 SO23-302-2-86 Revision 3
6.5.3.4 SO23-302-2-87 Revision 3

6.5.4 CPD-302-3-35 Sheet C Revision 0 – Instructions Type CV Voltage Relay

6.5.5 SO23-302-2-353 Revision 0 – Indoor Metal-Clad Switchgear

6.5.6 1814-AR286-M0008 Revision 0 - ABB Type SVF, SVF-1, SVF-3, SVF-31 Relays

6.5.7 SO123-306-6-16 Revision 0 – Volume 1 Digital Fault Recorder for Southern California Edison

6.5.8 1814-AU519-M0003 Revision 0 – Agilent (HP) 3458A Multimeter Specifications

6.6 Miscellaneous

6.6.1 Action Request AR050301091-65

6.6.2 SONGS Licensee Event Report No. 2005-003.

7 NOMENCLATURE

The following are in addition to the nomenclature of JS-123-103C (Reference 6.3.7).

AR	Action Request
ABB	Asea Brown Boveri
CCN	Calculation Change Notice
DAQ	Data Acquisition System
DGV	Degraded Grid Voltage
DGVSS	Degraded Grid Voltage Signal with SIAS
DO	Dropout
EC	Editorial Correction
EDG	Emergency Diesel Generator
ESF	Engineered Safety feature
kV	Kilovolt
LOVS	Loss of Voltage Signal
LSB	Least Significant Bit
MFR	Manufacturer
ms	Milliseconds
N/A	Not Available or Not Applicable
NCR	Non Conformance Report
NSP	Nominal Setpoint (SP)
NRC	Nuclear Regulatory Commission
PT	Potential Transformer/Voltage Transformer
PU	Pickup
SDVS	Sustained Degraded Voltage Signal

SIAS	Safety Injection Actuation Signal
SP	Setpoint
SRSS	Square Root Sum of the Squares
SWGR	Switchgear
SWYD	Switchyard
TCN	Technical Change Notice
Tol.	Tolerance
TLU	Total Loop Uncertainty
TS	Technical Specifications
UFSAR	Updated Final Safety Analysis Report
VA	Volt Ampere
V_{L-L}	Line to Line Voltage
V_{L-N}	Line to Neutral Voltage
V_T	Voltage Tap Setting
X	Reactance

8 CALCULATIONS

8.1 Calculation of Primary Element Allowance (PEA)

8.1.1 Calculation of the PT Burden

The total burden on each PT is the sum of the parallel burdens across its terminals which are phases A-B for one PT and B-C for the other. There are two circuits per 4kV bus. Each corresponding bus is loaded with identical loads. For example, referring to table 4.9.2, for circuit 1, the phase A-B Burden is:

$B_{AB} = B_{TDV} + B_{127D3} + B_{127F3} + B_{127R3}$

Where (from table 4.9.1):

$B_{TDV} = 0.2 + j0$ VA
$B_{127D3} = 0.5 + j0$ VA
$B_{127F3} = 0.7 + j2.3$ VA
$B_{127R3} = 15.15 + j\,7.72$ VA

Sum → $B_{AB} = 16.55 + 10.02$ VA $= 19.35 \angle 31.2^{\circ}$

The other burdens are calculated in a similar manner along with the average, minimum and maximum burdens at ±10 % difference from the average (per assumption 3.1.12). Note that the Synchroscope burden is not considered per Assumption 3.1.14.

Table 8.1.1

PT Transformer	Calculated Burden R + jX (VA)	Calculated Burden Z (VA) ∠ Angle (°)	Difference From the Average %
Undervoltage Circuit 1 B a-b	16.55 + j10.02	19.35 ∠31.2	-0.16
Undervoltage Circuit 1 B b-c	16.35 + j10.02	19.18∠31.5	+0.72
Undervoltage Circuit 2 B a-b	16.83 + j10.02	19.58∠30.8	-1.4
Undervoltage Circuit 2 B b-c	16.35 + j10.02	19.18 ∠31.5	+0.72
Average PT Burden	16.52 + j10.02	19.32 ∠31.2	N/A
Minimum per assumption 3.1.12 (-10 %)	14.87 + j9.02	17.39 ∠31.2	-1.93 (-10%)
Maximum per assumption 3.1.12 (+10 %)	18.17 + j11.02	21.25 ∠31.2	+1.93 (+10%)

Therefore, per assumption 3.1.12 the PT burden for all PT's will be 19.32 ∠31.2 (± 10%).

8.1.2 Calculation of the PT Ratio Correction Factor and Accuracy

As determined in Section 5.1.2, Equation 5-1 provides the RCF for the transformer for a given burden, with measured values of the true ratio and phase angle at zero burden, and one other burden. Manufacturer tag data from Attachment 9.1, along with the calculated burden for the transformer is used to find the applicable RCF, and thus the accuracy of the potential transformer voltage. (Note that the angles are all in radians.)

Equation 5-1

$$RCF_c = RCF_0 + \left[\frac{B_c}{B_t}\right]\left[(RCF_t - RCF_0)\times\cos(\theta_t-\theta_c)+(\gamma_t-\gamma_0)\times\sin(\theta_t-\theta_c)\right]$$

The following is an example of RCF Calculation for the average PT Burden:

$$RCF_c = 0.9974 + \left[\frac{19.32}{75}\right]\times\cdots$$
$$[(1.0019 - 0.9974)\times\cos(0.5548 - 0.5445)+\cdots$$
$$(-0.000582 - 0.000291)\times\sin(0.5548 - 0.5445)] = 0.9985568$$

$\Theta_t = \cos^{-1}(.85)$	= 31.79°	= 0.5548 radians	(Section 4.3, Y Burden)
Θ_c =	= 31.2°	= 0.5445 radians	(Table 8.1.1)
$RCF_0 = 0.9974$			(Section 4.3, No Burden)
$RCF_t = 1.0019$			(Section 4.3, Y Burden)
$B_c = 19.32$ VA			(Table 8.1.1)
$B_t = 75$ VA			(Section 4.3, Y Burden)
$\gamma_0 = +1$ minute	= 0.000291 radians		(Section 4.3, No Burden)
$\gamma_t = -2$ minutes	= -0.000582 radians		(Section 4.3, Y Burden)

RCF values were similarly calculated for the minimum and maximum burdens (as calculated in the previous section). The results, including percent error from the average RCF, are summarized in the following table:

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

Table 8.1.2

	Calculated Burden	Calculated RCF	RCF Percent Error from the Average
Average PT Burden	19.32 ∠31.2°	0.99856	N/A
Minimum per assumption 3.1.12 (-10% burden)	17.39 ∠31.2°	0.99844	-0.012 %
Maximum per assumption 3.1.12 (+10% burden)	21.25 ∠31.2°	0.99867	+0.012 %

Therefore the RCF to be used in the calculation of the setpoint is:

RCF = 0.99856

From Table 8.1.2, the error in the RCF due to a 10% burden uncertainty is ± 0.012 %. This uncertainty will be applied as a bias:

$PEA_{Burd} = \pm 0.012\%$

Assumption 3.1.9 specifies an additional independent, random error of 0.05% will be applied to the PT. Therefore:

$PEA_{PT} = \pm 0.05\%$

8.1.3 Voltage Drop from the PT to the UV Relay (PEA_{VD}).

Per assumption 3.1.15 a bias will be applied to the accuracy to account for the voltage drop from the PT to the UV Relay of -0.02 Vac maximum drop and 0 Vac minimum drop. Converting to percent:

$= -0.02/118*100 = -0.017\%$

Therefore:

$-PEA_{VD} = -0.017\%$ (Bias) and
$+PEA_{VD} = 0\%$ (Bias)

8.2 Calculation of Undervoltage Relay Total Loop Uncertainty (TLU)

8.2.1 Individual Uncertainties associated with Undervoltage Relay TLU

8.2.1.1 Primary Element Allowance (PEA) (as determined in section 8.1 above).

$PEA_{VD} = +0\% / -0.017\%$ (Bias)
$PEA_{PT} = \pm 0.05\%$ (SRSS)

PEA_{Burd} = ±0.012 % (Bias)

8.2.1.2 Device Tolerances

8.2.1.2.1 Drift Allowance (D)

Per assumption 3.2.2 the drift allowance for the Undervoltage Relay is:

D = ±0.1%

8.2.1.2.2 Power Supply Allowance (PSe)

Per design input Section 4.6 the DC power supply to the Undervoltage Relay varies no more than 103 to 140 Vdc under all operational conditions. The manufacturer's stated accuracy for allowable dc control power range from 100 to140 Vdc is ±0.1% (Section 4.2). Therefore the relay is operating within the manufacturer's allowable range and PSe is:

PSe = ±0.1%

8.2.1.2.3 Temperature Allowance (Te) (normal & accident)

The range of temperature operation for the ESF SWGR room vary from a low of 55 °F during normal conditions to a high of 95 °F during accident conditions (Section 4.4). This temperature range is bounding for normal conditions. Per Assumption 3.1.13 the relays will experience this same temperature difference. Therefore:

ΔT = 95- 55 = 40 F°

The manufacturers stated temperature effect is ± 0.4 % for a temperature range of 10 to 40 °C. Therefore the temperature effect is:

±0.4 / (40-10) * 5/9 = ±0.00741 %/F°

Then, the temperature effect (Te) is:

Te = ±0.00741 * 40 = ±0.297 %

8.2.1.2.4 Seismic Effect (Se)

Per Assumption 3.1.7 Seismic effect is negligible. Therefore,
Se = 0

8.2.1.2.5 Radiation Effect (Re)

Per Assumption 3.1.6 the Radiation effect is negligible. Therefore,
Re = 0

8.2.1.3 M&TE Tolerance (MTE)

See section 4.5 and assumption 3.1.3 for information regarding accuracy, ranges and conditions of use. Since the M&TE has an auto-range feature (switching to the 1000 Vac range at 120 Vac), the M&TE Tolerance is calculated for both the 100 Vac and 1000 Vac range, however only the larger uncertainty (1000 Vac range) is used in the TLU calculation. Note that these calculations are based on the *118* Vac point of interest as discussed in Assumption 3.1.1.

8.2.1.3.1 M&TE Accuracy (MTE_A)

The accuracy for the 100Vac range (120 Vac maximum reading) at 40Hz to 1kHz in the Synchronous mode is:

MTE_{A120} = ±(0.02% of reading + 0.002 % Range)
= ±(0.02% + 0.002% 120/*118*)
= ±0.*023* %

The accuracy for the 1000Vac range at 40Hz to 1kHz in the Synchronous mode is:

MTE_{A1k} = ±(0.04% of reading + 0.002 % Range)
= ±(0.04% + 0.002% 1000/*118*)
= ± 0.057 %

8.2.1.3.2 Readability (R) (least significant digit for digital M&TE)

R_{120} = ±0.00001 Vac
= ±0.00001 Vac/*118* Vac * 100 = ±0.00001%
≅ 0 (per Assumption 3.1.11)

R_{1k} = ±0.0001 Vac
= ±0.0001 Vac/*118* Vac * 100 = ±0.0001%
≅ 0 (per Assumption 3.1.11)

8.2.1.3.3 M&TE temperature effect (MTE_{Te})

Temperature Coefficient for reading outside of ± 1.8 F° (± 1 C°) of the last ACAL is ±(0.001% of reading + 0.0001 % Range)/C° therefore based on assumption 3.1.3 of a calibration temperature range of ± 9 F° (± 5 C°) and converting to F° from C°:

MTE_{Te120} = ±(0.001 + 0.0001 * 120/*118*)* 5/9* 9 % = ±0.006 %
MTE_{Te1k} = ±(0.001 + 0.0001 * 1000/*118*)* 5/9* 9 % = ±0.010 %

8.2.1.3.4 M&TE Reference Standards (MTE_{RS})

The reference standard accuracy is assumed to be 25% of the M&TE accuracy per JS-123-103C (reference 6.3.7). Therefore:

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

MTE_{RS120} = 0.023 % * 0.25 = ±0.006 %
MTE_{RS1k} = 0.057 % * 0.25 = ±0.015 %

8.2.1.3.5 Total M&TE Tolerance
The total M&TE allowance is the SRSS of the four components determined above. That is:

$$MTE = \pm (MTE_A^2 + R^2 + MTE_{Te}^2 + MTE_{RS}^2)^{1/2}$$

$$MTE_{120} = \pm (0.023^2 + 0^2 + 0.006^2 + 0.006^2)^{1/2}$$
$$MTE_{120} = \pm 0.025\%$$

$$MTE_{1k} = \pm (0.057^2 + 0^2 + 0.010^2 + 0.015^2)^{1/2}$$
$$MTE_{1k} = \pm 0.060\%$$

Therefore, applying the greater (1kV range) allowance:

MTE = ± 0.060%

8.2.1.4 Setting Tolerance (ST)
Per Assumption 3.1.2 the setting tolerance is ±0.1 Vac, therefore:

ST = ±0.1/118*100 = ±0.085%

8.2.1.5 Miscellaneous Allowance (Ma)
Per assumption 3.1.10 the miscellaneous allowance is:

Ma = ±0.1 %

8.2.2 Combination of Uncertainties

Combining the uncertainties per the equation from Section 5.2.2, the TLU is:

$$TLU = \pm\sqrt{Te^2 + D^2 + PSe^2 + Se^2 + Re^2 + MTE^2 + ST^2 + Ma^2 + PEA_{PT}^2} \pm PEA_{BURD} \pm PEA_{VD}$$

$-PEA_{VD}$ = -0.017%
$+PEA_{VD}$ = 0 %
PEA_{BURD} = ±0.012%
PEA_{PT} = ±0.05%
Te = ±0.297%
D = ±0.1%
PSe = ±0.1%
Se = N/A
Re = N/A
MTe = ±0.060%

ST $= \pm 0.085\%$
Ma $= \pm 0.1\%$

$+TLU = +(0.297^2 + 0.1^2 + 0.1^2 + 0^2 + 0^2 + 0.060^2 + 0.085^2 + 0.1^2 + 0.05^2)^{1/2} + 0.012 + 0\% = +0.375\%$
$-TLU = -(0.297^2 + 0.1^2 + 0.1^2 + 0^2 + 0^2 + 0.060^2 + 0.085^2 + 0.1^2 + 0.05^2)^{1/2} - 0.012 - 0.017\% = -0.392\%$

Rounding conservatively to the larger TLU value:

TLU $= \pm 0.40\%$ OR
$= \pm 0.40\% * 118$ $= \pm 0.48$ Vac at the UV Relay OR
$= \pm 0.40\% * 118 * (35 * 0.99856)$ $= \pm 16.5$ Vac at the 4kV Bus

8.3 Calculation of Undervoltage Relay Allowable Value Tolerance (AVT)

The allowable value allowable values during surveillance test (relay only)

$$AVT = \sqrt{D^2 + ST^2 + R^2}$$

ST = Setting Tolerance: $\pm 0.085\%$.
D = Drift: $\pm 0.1\%$
R = Readability of M&TE: $= \pm 0.00001 / 118$ Vac
$= 0.00001\% \cong 0$ (Negligible per 3.1.11)

Therefore, the Tolerance for allowable value is:

AVT $= \pm(0.085^2 + 0.1^2 + 0^2)^{1/2}\%$ $= \pm 0.132\%$ OR
$= \pm 0.132\% * 118$ $= \pm 0.16$ Vac at the UV Relay OR
$= \pm 0.132\% * 118 * (35 * 0.99856)$ $= \pm 5.5$ Vac at the 4kV Bus

8.4 Calculation of Undervoltage Relay PU and DO Setpoints

8.4.1 Undervoltage Relay Undervoltage Dropout (DO) Setpoint (SP_{DO})

8.4.1.1 Calculation of Dropout (DO) Setpoint SP_{DO}

The undervoltage relay dropout *setpoint*, is determined by:

$SP_{DO} = AL_L + (+TLU) + M$

$SP_{DO} = 4106 + 16.5 + 6$ = *4128.5 Vac at the 4kV Bus OR*
$SP_{DO} = (4106 + 16.5 + 6)/(35 * 0.99856)$ = *118.13 Vac at the UV Relay*

8.4.2 Undervoltage Relay Pickup (Reset) Voltage Setpoint (SP_{PU})

8.4.2.1 Calculation of Relay Pickup Setpoint SP_{PU}

Based on the method outlined in section 5.4.2.1, the Relay Pickup Voltage Setpoint is determined by adding the deadband of 0.3 Vac (see 3.2.1) to the Dropout (DO) Setpoint (SP_{DO}), Therefore:

$SP_{PU} = SP_{DO} + DB = 118.13 + 0.3$ **= *118.43* Vac at the UV Relay OR**
$SP_{PU} = 118.43 * (35 * 0.99856)$ **= *4139.1* Vac at the 4 kV bus**

8.4.2.2 Determination of Margin of PU Setpoint to the PU Upper Analysis Limit (M_{PU})

$M_{PU} = AL_{PU} - (SP_{PU} - (-TLU))$
$M_{PU} = 4161 - 4139.1 - 16.5$ ***= 5.4 Vac at the 4 kV bus***

8.5 Calculation of Undervoltage Relay PU and DO As-Found/As-Left Acceptance Bands

8.5.1 Calculation of Undervoltage Relay As-Found Acceptance Band

The As-Found Acceptance band will be the relay pickup or dropout setpoint ±AV (allowable value).

As-Found Band for Dropout = *118.13* ±0.16 Vac
= *117.97* to *118.29* Vac at the UV Relay OR
= *4128.5* ±5.5 Vac
= *4123.0* to *4134.0* Vac at the 4kV Bus

As-Found Band for Pickup = *118.43* ±0.16 Vac
= *118.27* to *118.59* Vac at the UV Relay OR
= *4139.1* ±5.5 Vac
= *4133.6* to *4144.6* Vac at the 4kV Bus

8.5.2 Calculation of Undervoltage Relay As-Left Acceptance Band
The As-Left Acceptance band will be the trip or reset setpoint ±ST (setting tolerance).

As-Left Band for Dropout = *118.13* ±0.1 Vac = ***118.03* to *118.23* Vac**
As-Left Band for Pickup = *118.43* ±0.1 Vac = ***118.33* to *118.53* Vac**

8.6 Calculation of Minimum and Maximum Relay DO and PU at the 4kV Level

The Minimum and Maximum Relay DO and PU Values are calculated by applying the TLU to the nominal setpoint. Results are rounded conservatively (up for maximum, down for minimum).

Maximum PU = (*118.43* + 0.48) **= *118.91* Vac at the UV Relay OR**
= (*118.43* + 0.48)*(35 * 0.99856) **= *4155.9* Vac at the 4kV Level**

Maximum DO = (*118.13* + 0.48) **= *118.61* Vac at the UV Relay OR**
= (*118.13* + 0.48)*(35 * 0.99856) **= *4145.4* Vac at the 4kV Level**

Minimum PU = (*118.43* − 0.48) **= *117.95* Vac at the UV Relay OR**

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0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
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$= (118.43 - 0.48)*(35 * 0.99856)$ = **4122.3** **Vac at the 4kV Level**

Minimum DO $= (118.13 - 0.48)$ = **117.65** **Vac at the UV Relay OR**
$= (118.13 - 0.48)*(35 * 0.99856)$ = **4111.8** **Vac at the 4kV Level**

9 ATTACHMENTS

9.1 Potential Transformer Data Tag

This tag was copied during a walk-down of the SONGS Mesa warehouse spares. Three spare were located, one spare did not have a tag, all data on the other two tags were identical except for the serial numbers.

Type JVM-3 763X021026

Ratio 35:1 Ser# 5868022

Rated Secondary Volts 120 Test Frequency 60 HZ

Secondary Burden	Secondary Volts	Ratio Correction Factor	Phase Angle (minutes)
0 VA	120	0.9974	+1
Y	120	1.0019	-2

Date: 2/11/04 Tested by: DC

GE Instrument Transformers

GE certifies that this instrument transformer has received insulation and accuracy tests and that it is satisfactory for the rated IEEE C57.13 insulation level and accuracy classes. The data presented are traceable to the National Institute of Standards and Technology.

E&TS DEPARTMENT

CALCULATION SHEET

Project or ECP: SONGS 2 & 3 Calc No. E4C-130

Subject: TLU Calc for Undervoltage Relay Circuits at Class 1E 4 KV Switchgear Sheet 39 of 48

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

9.2 Westinghouse V-2 Transducer Data Sheet

Application Data 43-860 Page 30

Type V-2 Transducers

Part II
Specifications and Technical Data

3. Type V12-841 Current Transducer

(a) Specifications

Standard Input..................0-5 amps

Special Input....................Single and multi-ranges up to 20 amps

Frequencies.....................60 Hz (useable on 50 Hz and 400 Hz)

Output...........................1 mA, isolated

Load Resistance.................10,000 ohms ±1%

Linearity.........................±1%, included in accuracy rating

Accuracy.........................±1% at reference conditions with 50 ohm load

Loss..............................0.2 volt amperes

Warm Up Time...................Negligible

Response Time...................0.15 seconds, maximum

Ambient Temperature Influence....1% maximum for ±10°C change from 25°C

Extreme Temperature Influence....2%, 25°C to 65°C
2%, 25°C to −20°C

Frequency Influence..............±1.0% for maximum for ±10% change in frequency

Dielectric Test...................1500 volts rms

Working Voltage to Ground.......1100 volts peak

Permissible Overload
(Percent of Rating)..............Continuous, 200%
5 seconds, 500%
1 second, 1000%

Ripple............................48% (see Part 1, Section L, page 27)

Maximum Current................5 amps

4. Type VE2-841 Voltage Transducer

Same as for V12-841 (Paragraph 3) except:

Standard Input.....0-150 volts
Loss...............0.2 volt-amperes
Response Time.....2.0 seconds

5. Type VE2-841 Suppressed Zero Voltage Transducer

Same as for V12-841 (Paragraph 3) except:

Standard Input.....110-130 volts
Loss...............0.5 volt-amperes
Accuracy......................0.33% of center value

Westinghouse Electric Corporation
Relay Instrument Division, Newark, N. J. 07101
Printed in USA

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

9.3 Correspondence with ABB Engineering Concerning Type 27N Relay

don.p.steltz@us.abb.com
04/29/2005 01:15 PM

To: whittlcb@songs.sce.com
cc: conklilt@songs.sce.com, kimjl@songs.sce.com, summyjs@songs.sce.com
Subject: Re: Type 27N Relay Model 411T5375 Specifications.

Butch
As long as the adjustment can be made there is no problem with the relay. Again the only thing to watch for is relay chatter if the pick up and drop out are set to close and the voltage input varies. Time delay should take care of this.

There will be no problmes in operating the relay at this setting

Thanks
Don

Message from whittlcb@songs.sce.com received on 04/29/2005 10:54 AM

04/29/2005 10:54 AM whittlcb@songs.sce.com

To: Don P. Steltz/ALL/USTRA/ABB@ABB
cc: conklilt@songs.sce.com, summyjs@songs.sce.com, kimjl@songs.sce.com
Subject: Type 27N Relay Model 411T5375 Specifications.

Hi Don,
I just noticed that my original email stated that we were setting our 27N Relay deadband at 0.3%. This should have been 0.3 Vac. This is equal to 0.254% of our approximately 118 Vac trip. Our technicians have been able to make this adjustment on the bench.

Please let me know if this is alright.

Thanks,
Butch Whittle
463-3599

----- Forwarded by BUTCH WHITTLE/SONGS/SCE/EIX on 04/29/2005 07:47 AM -----

BUTCH WHITTLE
04/18/2005 12:47 PM

To: don.p.steltz@us.abb.com
cc: LINDA CONKLIN/SONGS/SCE/EIX@SCE, JEFF SUMMY/SONGS/SCE/EIX@SCE, JOON IL KIM/SONGS/SCE/EIX@SCE, ALEX BAGHAEI/SONGS/SCE/EIX@SCE,

PROMILA K

KIMBERLY

411T5375

DUTT/SONGS/SCE/EIX@SCE,

MOSLEY/SONGS/SCE/EIX@SCE, CECIL BAZLEY/SONGS/SCE/EIX@SCE

Subject: Type 27N Relay Model Specifications.

To: Mr. Don Steltz of ABB Power

Dear Mr. Steltz,

As you know, San Onofre Nuclear Generating Station has a number of ABB Type 27N Relays (Model #411T5375 with HF filter). We are currently involved in a effort to reduce the uncertainties associated with the PU and DO voltage setpoints. Additionally we wish to reduce the deadband (difference between the PU and DO voltages) to 0.3 % versus the ABB specified 0.5%.

I would like to verify the following information that I received per our telephone conversation today.

1.) Effect of Reduced Deadband on Accuracy: The deadband is field adjustable and can be set to less than the specified 0.5% with no effect on the basic 0.1 % accuracy of the relay PU and DO voltages. The prmary consideration of reduced deadband would be the cycling of the relay, if the voltage were to swing rapidly. SONGS currently is using a 2 second delay and therefore this effect would be minimized.

2.) Temperature Effect: Per the test data that we received from ABB, the temperature effect is linear over the 10 - 40 degree C temperature range. Therefore, if we reduce the operational temperature band by one-half the uncertainty will be reduced by one-half. That is, the uncertaintly due to the temperature effect would be reduced from 0.4% to 0.2%.

3.) Drift (time related): ABB recommends a recalibration interval of one to two years to ensure that the accuracy of the relay is maintained within the 0.1% repeatability specified. Therefore, the relay is relatively stable with respect to time and should drift by no more that 0.1% in 24 months. If you have any additional data concerning drift, I would appreciate a copy.

Thanks,
C B Whittle
(949) 463-3599

9.4 Correspondence with GE Confirming Potential Transformer Model Number Change.

"Tenhaagen, Chris \(GE Energy\)" <chris.tenhaagen@ge.com>
05/02/2005 08:09 PM

To: <whittlcb@songs.sce.com>
cc: <kimji@songs.sce.com>
Subject: RE: Type JVM-3 Model Numbers 643X94 versus Model Number 763X02

Butch
Yes, 643x94 was the old 6 digit cat number, replaced by by the current 10 digit system. On our structure, it reads like this:

```
  ATRITR        TRANSFORMER                         5/02/05   23:01:07   ATRIT1
      PART NUMBER: 643X094000
 TYPE          JVM-3         MODEL  VT         RATIO      35:1
 HERTZ              50-60    BIL        60     SEC.VOLTS               120
 REC KEEP                N   WEIGHT            PRI VOLTS               4200
 CUSTOMER NUMBER             NSV               RF/VA/KVA AT 30C          750
 ON NP  643X094000                             RF/VA/KVA AT 55C          500
 ACC CL AT 60 HZ 0.3 W,X,M,Y                              PALLET       PACK

                               M    E    M    O
          REPLACED BY 763X021026
```

The analysis I provided should apply very closely for both old and new products.
Chris

-----Original Message-----
From: whittlcb@songs.sce.com [mailto:whittlcb@songs.sce.com]
Sent: Monday, May 02, 2005 5:16 PM
To: Tenhaagen, Chris (GE Energy)
Cc: kimji@songs.sce.com
Subject: Type JVM-3 Model Numbers 643X94 versus Model Number 763X02

Hi Chris,

We have Model number 643X94 installed in the plant versus the model 763X02 that we have in the wearhouse. Is the Tag Data from the warehouse transformers applicable to the installed transformers? I can't find any information in the online resources for the older (installed) transformers.

Thanks,
C B Whittle
(949) 463-3599 (cell)

9.5 Degraded Voltage Relay Cable Voltage Drop Calculation

1. Purpose/Scope

The purpose of this Attachment is to calculate the maximum voltage drop in the cable between the potential transformer (PT) and the degraded voltage relay (27N). The affected relays are those located in 4.16 kV Switchgears 2A04, 2A06, 3A04 and 3A06.

2. Results/Conclusions

The maximum cable voltage drop between the secondary terminals of the potential transformer and the degraded voltage relay is 0.02 volts.

3. Assumptions

Assumptions Requiring Verification

NONE

Assumptions Not Requiring Verification

3.1 The longest cable length between the fuse and the degraded voltage relay terminal is assumed to be at the Switchgear 2A04. In Switchgear 2A04, the fuse is located in Cubicle 15 and the relay is in Cubicle 21. The total length of this section in the switchgear is 17 feet and 8 inches (See Reference 6.1.1). The height is approximately 7 feet and 6 inches. The total cable length is approximated at 40 feet, with some margins.

3.2 The potential transformers and the fuses are located in Cubicle 15 (same for all four switchgears). The cable length between the secondary of the potential transformer and the fuse is assumed as 15 feet. See Reference 6.1.1.

3.3 It is assumed that all potential transformer load, except the degraded voltage relay (Z_2), can be approximated as one lumped load (Z_1) as shown in Figure 1.

4. Design Inputs

4.1 The 4.16 kV Switchgear 2(3)A04 and 2(3)A06 bus potential transformers are located in Cubicle 15. See References 6.1.1 to 6.1.14.

4.2 At 4.16 kV Switchgear 2A04, 2A06, 3A04 and 3A06, the degraded voltage relays are located in Cubicle 21, 17, 20 and 17, respectively. See References 6.1.1 to 6.1.14.

4.3 Cable size #12 AWG is used between the secondary terminals of potential transformer and fuse. See References 6.1.1 to 6.1.14.

4.4 Cable size #14 AWG is used between the fuse and degraded voltage relay terminal.

4.5 Per E4C-086, Section 4.5 (Reference 6.4.1), the cable impedance of a #12 AWG and #14 AWG is:

$Z_{\#14AWG} = 0.3135 + j\ 0.00765$ ohms/100 ft

$Z_{\#12AWG} = 0.1972 + j\ 0.00710$ ohms/100 ft

The cable resistance is based on an ambient temperature of 75°C.

4.6 The burden of degraded voltage relay (127D-1, 2, 3 & 4) is 0.5 VA (purely resistive) per Reference 6.3.1

4.7 The burden of loss of voltage relay (127F-1, 2, 3 & 4) is 0.7 + j 2.3 VA per Reference 6.3.2.

4.8 The burden of residual voltage relay (127R-1, 2, 3 & 4) is 0.288 VA (purely resistive) per Reference 6.3.3.

4.9 The burden of digital fault recorder (DFR) is 0.288 VA (purely resistive) per Reference 6.3.4, page I-21.

4.10 The burden of voltage transducer TDV1 is 0.2 VA per Attachment 9.2

4.11 The maximum switchgear room temperature is 95°F per Reference 6.4.2.

5. Methodology

5.1 The voltage drop across the cable between the secondary of the potential transformer and the degraded voltage relay will be calculated using the rated burden at 120 Vac. The total PT burden will be divided into two groups. Loads that are located in the Cubicle 15 will be lumped into one group (Z_1). The other burden will be the degraded relay (Z_2)

5.2 The impedance of the fuse and the test switch will be ignored in the calculation. However, a margin will be added to the calculated total voltage drop to account for voltage drop in the fuse and the test switch.

6. References

6.1 Design Drawings

6.1.1 30107 Rev 14, Oneline, 4160V Switchgear Bus 2A04 (ESF)

6.1.2 30220 Sheet 1, Rev 12, Elementary, 4.16 kV Bus 2A04 Metering

6.1.3 31763 Sheet 15, Rev 14, Wiring Diagram, 4160V Switchgear 2A04

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

6.1.4 31763 Sheet 21A, Rev. 1, Wiring Diagram, 4.16kV Switchgear 2A04

6.1.5 30109 Rev 15, Oneline, 4160V Switchgear Bus 2A06 (ESF)

6.1.6 30230 Sheet 1, Rev 14, Elementary, 4.16 kV Bus 2A06 Metering

6.1.7 31764 Sheet 15, Rev 18, Wiring Diagram, 4160V Switchgear 2A06

6.1.8 31764 Sheet 17A, Rev. 1, Wiring Diagram, 4.16kV Switchgear 2A06

6.1.9 32107 Rev 14, Oneline, 4160V Switchgear Bus 3A04 (ESF)

6.1.10 32220 Sheet 1, Rev 10, Elementary, 4.16 kV Bus 3A04 Metering

6.1.11 33763 Sheet 4, Rev 1, Wiring Diagram, 4160V Switchgear 3A04

6.1.12 32109 Rev 17, Oneline, 4160V Switchgear Bus 3A06 (ESF)

6.1.13 32230 Sheet 1, Rev 9, Elementary, 4.16 kV Bus 3A06 Metering

6.1.14 33764 Sheet 4, Rev 1, Wiring Diagram, 4160V Switchgear 3A06

6.2 Vendor Drawings

6.2.1 SO23-302-2-131 Rev. 1, Connection Diagram, Bus 2A04 and 3A04

6.2.2 SO23-302-2-141 Rev. 1, Connection Diagram, Bus 2A06 and 3A06

6.2.3 SO23-302-2-452 Rev. 7, Connection Diagram, Bus 3A04 Cubicle 15

6.2.4 SO23-302-2-396 Rev. 6, Connection Diagram, Bus 3A06 Cubicle 15

6.3 Vendor Instructional Manuals

6.3.1 SO23-302-2-518 Rev. 0, Instruction Manual for ABB Type 27N High Accuracy Relay

6.3.2 CPD-302-3-35 Sheet C, Rev. 0, Instructions Manual Type CV Voltage Relay

6.3.3 1814-AR286-M0008 Rev. 0, ABB Type SVF, SVF-1, SVF-3, SVF-31 Relays

6.3.4 SO123-306-6-16 Rev. 0, Volume 1, Digital Fault Recorder for Southern California Edison.

6.4 Calculations

6.4.1 E4C-086 Rev. 5, SONGS 2 & 3 Data Development and Documentation

6.4.2 M-0073-061 ICCN C-12, Normal Environmental Conditions for the 4kV Switchgear Protective Relay Setting Calculation.

7. Calculations

REV	ORIGINATOR	DATE	IRE	DATE	REV	ORIGINATOR	DATE	IRE	DATE	REV INDICATOR
0	C. B. Whittle	5/16/2005	Joshua Park	5/16/2005						
1	C. B. Whittle	5/24/2005	Joshua Park	5/24/2005						

PT Circuit #2 has more loads connected than PT Circuit #1. Therefore, PT Circuit #2 will be used to evaluate the total voltage drop in the cable. See also tables in Section 4.9.1 and 4.9.2 of the main section of this calculation.

Figure 1 shows a simplified connection diagram used to calculate the cable voltage drop for the degraded voltage relay:

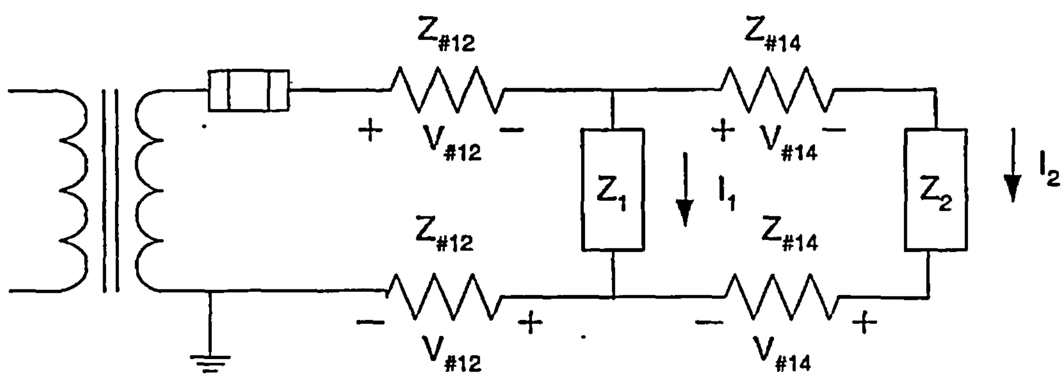

Figure 1. Degraded Voltage Relay cable voltage drop calculation

Where

$Z_{\#12}$	is the cable impedance of #12 AWG
$Z_{\#14}$	is the cable impedance of #14 AWG
Z_1	is the burden of connected loads not including the degraded voltage relay
Z_2	is the burden of degraded voltage relay
$V_{\#12}$	Voltage drop across cable #12 AWG
$V_{\#14}$	Voltage drop across cable #14 AWG
I_1	Load current
I_2	Degraded voltage relay load current

7.1 Calculate Load Burden

Current I_1 is calculated by dividing the total load volt-amperes by the rated voltage. The connected loads are 127R, 127F, digital fault recorder and the voltage transducer.

$$S_{127R} = 15.15 + j\,7.72 \quad \text{VA}$$

$$S_{127F} = 0.7 + j\,2.3 \quad \text{VA}$$

$$S_{DFR} = 0.288 + j\,0 \quad \text{VA}$$

$S_{TDV1} = 0.2 + j\,0$ VA

$S_1 = S_{127R} + S_{127F} + S_{DFR} + S_{TDV1}$

$= 16.4 + j\,10.02$ VA

$S_2 = 0.5 + j\,0$ VA

7.2 Calculate Cable Resistance at 95°F (35°C)

The cable resistance is calculated using equation:

$R_2 = R_1 * (234.5 + T_2) / (234.5 + T_1)$

Where

T_1 is 75°C

R_1 is the resistance at 75°C

T_2 is 35°C

R_2 is the resistance at 35°C

The cable resistance at 35°C is:

$Z_{\#14AWG} = 0.2730 + j\,0.00765$ ohms/100 ft

$Z_{\#12AWG} = 0.1717 + j\,0.00710$ ohms/100 ft

7.3 Calculate Load Current

$I_1 = S_1 / 120 \angle 0°$

$= 0.14 + j\,0.084$ A

$= 0.163 \angle 30.96°$ A

$I_2 = S_2 / (120 \angle 0°)$

$= 0.0042 \angle 0°$ A

7.4 Calculate Cable Impedance

Cable impedance is double to account for the return path. The circuit is only grounded at one point in Cubicle 15.

$Z_{\#14}$ $= 2 * (40\text{ ft} / 100\text{ ft}) * [\,0.2730 + j\,0.00765]$ ohms

$= 2* (0.1092 + j\,0.0031)$ ohms

$= 0.2184 \angle 1.63°$ ohms

$Z_{\#12}$ $= 2 * (15\text{ ft} / 100\text{ ft}) * [\,0.1717 + j\,0.00710]$ ohms

$= 2 * (0.0258 + j\,0.001065)$ ohms

$= 0.0516 \angle 2.36°$ ohms

7.5 Calculate Total Voltage Drop

ΔV_2 $= I_2 * Z_{\#14}$

$= (0.0042 \angle 0°\text{ A}) * (0.2184 \angle 1.63°\text{ ohms})$

$= 0.000917 \angle 1.63°$ V

ΔV_1 $= (I_1 + I_2) * Z_{\#12}$

$= (0.1669 \angle 30.22°\text{ A}) * (0.0516 \angle 2.36°\text{ ohms})$

$= 0.00861 \angle 32.58°$ V

ΔV_{total} $= \Delta V_1 + \Delta V_2$

$= 0.0082 + j\,0.0047$

$= 0.0095 \angle 29.8°$ V

The maximum calculated cable voltage drop between the potential transformer secondary terminals and degraded voltage relay is 0.0095 volts. This voltage drop does not account for any drops across the fuse and the test switch contacts. To account for these additional drops, the calculated value will be conservatively doubled or <u>0.02 volts</u>.