Charles R. Pierce
Regulatory Affairs Director

Southern Nuclear
Operating Company, Inc.
40 Inverness Center Parkway
Post Office Box 1295
Birmingham, AL 35242

Tel 205.992.7872
Fax 205.992.7601

SOUTHERN NUCLEAR
A SOUTHERN COMPANY

January 12, 2016

Docket Nos.: 50-348
50-364

NL-16-0007

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555-0001

Joseph M. Farley Nuclear Plant, Units 1 and 2
Technical Specification 3.3.5
Loss of Power Diesel Generator Start Instrumentation
Supplement to License Amendment Request

Ladies and Gentlemen:

In accordance with the requirements of 10 CFR 50.90, Southern Nuclear Operating Company (SNC) submitted a request via a letter dated November 20, 2015 (NL-15-0722), for an amendment to the Joseph M. Farley Nuclear Plant (FNP) Units 1 and 2 Technical Specifications (TS). That amendment request proposes to revise TS 3.3.5, "Loss of Power Diesel Generator Start Instrumentation," to enable compliance with a license condition for each unit which requires elimination of manual actions as part of the FNP degraded voltage protection scheme.

Included in the proposed changes to TS 3.3.5 are new voltage and delay time Allowable Values for the 4.16 kV Emergency Bus Degraded Grid Voltage Actuation function. As a supplement to the November 20, 2015 license amendment request, enclosed are copies of the calculations which support these new Allowable Values.

Enclosures 1 and 2 are the calculations which established the delay times for the degraded grid voltage relays for Units 1 and 2, respectively; Enclosure 3 is the calculation which established the relay actuation voltages for both units. Provided are the bodies of the calculations, which detail the methodology employed and the results obtained. The attachments to the calculations have been omitted since their inclusion would add several hundred pages of material only peripheral to the requested changes (such as modeling software output reports, relay manufacturer's specifications, etc.).

In accordance with the requirements of § 50.91, a copy of this supplement to SNC's November 20, 2015 license amendment request is provided to the designated Alabama official.

This letter contains no NRC commitments. If you have any questions, please contact Ken McElroy at (205) 992-7369.

Mr. Pierce states he is Regulatory Affairs Director of Southern Nuclear Operating Company, is authorized to execute this oath on behalf of Southern Nuclear Operating Company and to the best of his knowledge and belief, the facts set forth in this letter are true.

Respectfully submitted,

C. R. Pierce

C. R. Pierce
Regulatory Affairs Director

*Sworn to and subscribed before me this* 12th *day of* January*, 2016.*

Laura L. Crumpk
*Notary Public*

*My commission expires:* 10-8-2017

CRP/DWD/cg

Enclosures:
1. FNP Unit 1 Calculation SE-SNC529029-001 - Minimum Expected Voltage Study
2. FNP Unit 2 Calculation SE-SNC529029-002 - Minimum Expected Voltage Study
3. FNP Units 1 & 2 Calculation SJ-SNC529029-001 - Determination of Setpoints

cc: <u>Southern Nuclear Operating Company</u>
Mr. S. E. Kuczynski, Chairman, President & CEO
Mr. D. G. Bost, Executive Vice President & Chief Nuclear Officer
Ms. C. A. Gayheart, Vice President – Farley
Mr. D. R. Madison, Vice President – Fleet Operations
Mr. M. D. Meier, Vice President – Regulatory Affairs
Mr. B. J. Adams, Vice President – Engineering
Ms. B. L. Taylor, Regulatory Affairs Manager – Farley
RType: CFA04.054

<u>U. S. Nuclear Regulatory Commission</u>
Mr. L. D. Wert, Regional Administrator
Mr. S. A. Williams, NRR Project Manager - Farley
Mr. P. K. Niebaum, Senior Resident Inspector - Farley

<u>Alabama Department of Public Health</u>
Dr. D. E. Williamson, State Health Officer

**Joseph M. Farley Nuclear Plant, Units 1 and 2**
**Technical Specification 3.3.5**
**Loss of Power Diesel Generator Start Instrumentation**
**Supplement to License Amendment Request**

**Enclosure 1**

**FNP Unit 1 Calculation SE-SNC529029-001**
**Minimum Expected Voltage Study**

(Attachments to calculation not included)

SOUTHERN COMPANY
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**Southern Nuclear Design Calculation**

| **Calculation Number:** |
|---|
| SE-SNC529029-001 |

| **Plant:** J.M. Farley Nuclear Plant | **Unit:** ☑ 1 ☐ 2 ☐ 1 & 2 | **Discipline:** Electrical |
|---|---|---|
| **Title:** Unit 1 Minimum Expected Voltage Study | | **Subject:** AC System Analysis |
| **Purpose / Objective:** Determine safe operating limits of Unit 1 under degraded grid conditions | | |
| **System or Equipment Tag Numbers:** R01, R11, R15, R16, R17 | | |

**Contents**



**Nuclear Quality Level**

☑ **Safety-Related** ☐ **Safety Significant** ☐ **Non- Safety –Significant**

**Version Record**

| **Version No.** | **Description** | **Originator** Printed Name Initial / Date | **Reviewer** Printed Name Initial / Date | **Approval 1** Printed Name Initial / Date | **Approval 2** Printed Name Initial / Date |
|---|---|---|---|---|---|
| 1.0 | Issued per RER SNC529029, v1.0 | Kaleb Drew KD 4/30/15 | Matt Lane ML 4/30/15 | Kevin Littrell KRL 4/30/15 | John Minley JEM 6-22-15 |

Notes: An OE search has been performed and the results are documented in the Methodology Section.

**Version History:**

Version 1.0: Initial version issued for RER SNC529029.

**Design Inputs:**

1. SE-94-0470-001, Ver. 7.0, "Unit 1 As-Built Load Study": Primary calculation input; source of ETAP model and methodology used for case study runs.
2. SE-94-0470-004, Ver. 4.0, "Unit 1 Load Study Summary": LOCA starting and steady-state requirements tables modified for use as Attachment 1 of this calculation.
3. SJ-SNC529029-001, Ver. 1.0, "Determination Of Setpoints, Reset Points, And Loop Uncertainties For 4160V Safety-Related Degraded Voltage Relay (DVR) Loops (Buses 1F, 2F, 1G And 2G)"

**References:**


1. GDC 17, "General Design Criteria for Nuclear Power Plants 17"
2. IEEE Standard 399-1997, "IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis"
3. NRC Regulatory Issue Summary 2011-12, Revision 1, "Adequacy of Station Electric Distribution System Voltages": Guidance for degraded grid analysis acceptance criteria and methodology
4. Farley Nuclear Plant Units 1 & 2 Tech Spec Bases, Rev. 65
5. Farley Nuclear Plant Unit 1 Tech Spec, Amendment 195
6. Farley Nuclear Plant Units 1 & 2 FSAR, Rev. 26, Feb. 2015
7. SM-90-1653-002, Ver. 23.0, "Reduced Voltage Torque/Thrust Capability for Gate & Globe Valves in the FNP MOV Program"
8. SM-90-1653-009, Ver. 8.0, "Reduced Voltage Torque Capability for Butterfly Valves in the FNP MOV Program"
9. SM-1053039201-001, Ver. 1.0, "Develop Design Basis Calculations for the Penetration Room Filter Dampers"
10. DOEJ-FRSNC52029-M001, Ver. 1.0, "Evaluation of Reduced Voltage Requirements for Motor Operated Valves for use in the Degraded Voltage Protection Plan"
11. E-035.01.A, Ver. 6.0, "Setting of Protective Relays for 4.16kV Auxiliary Power System"
12. SE-90-1845-2-PE, Ver. 8.0, "Large, Small, and SBO Diesel Dynamic Study"
13. SE-91-1976-1, Ver. 6.0, "Motor Starter Control Circuit Study"
14. SE-91-1925-14-PE, Ver. 1.0, "MOV3232A,B,C: Terminal Voltage at End of Stroke"
15. SE-99-9472-001, Ver. 1.0, "Stability Review for LOSP/DGG Relay Operation"
16. SE-94-0-0378-001, Ver. 5.0, "MOV Combination Starter Component Sizes and Settings"
17. SE-99-0-2010-001, Ver. 0.0, "Verification Package for Computer Software Used to Calculate MOV Thermal Overload Heater Sizes"
18. SE-90-1714-12, Ver. 4.0, "Overload Heater Sizing and Resistance"
19. NEMA MG 1-2003, "Motors and Generators"
20. 1995 SER, February 23, 1995, "Safety Evaluation for Degraded Grid Voltage Relay Set Points"
21. IB 7.4.1.7-7, Issue E, ABB Instructions Single Phase Voltage Relays
22. GEH-1768G, "GE Instructions: Undervoltage Relays"
23. MC-F-06-0143, Ver. 1.0

24. MC-F-07-0014, Ver. 1.0
25. MC-F-07-0050, Ver. 2.0
26. MC-F-07-0110, Ver. 1.0
27. MC-F-07-0116, Ver. 1.0
28. MC-F-08-0017, Ver. 3.0
29. MC-F-08-0026, Ver. 1.0
30. MC-F-08-0076, Ver. 1.0
31. MC-F-08-0083, Ver. 1.0
32. MC-F-08-0091, Ver. 1.0
33. MC-F-08-0162, Ver. 1.0
34. MC-F-08-0194, Ver. 1.0
35. MC-F-10-0003, Ver. 1.0
36. MC-F-10-0005, Ver. 1.0
37. MC-F-10-0037, Ver. 1.0
38. MC-F-10-0094, Ver. 1.0
39. MC-F-10-0127, Ver. 1.0
40. MC-F-11-0022, Ver. 1.0
41. MC-F-11-0077, Ver. 1.0
42. MC-F-11-0090, Ver. 1.0
43. MC-F-12-0002, Ver. 1.0
44. MC-F-12-0031, Ver. 1.0
45. MC-F-12-0071, Ver. 3.0
46. MC-F-12-0086, Ver. 2.0
47. MC-F-13-0087, Ver. 1.0
48. MC-F-14-0009, Ver. 1.0
49. MC-F-14-0029, Ver. 1.0
50. MC-F-15-0051, Ver. 1.0
51. CCN-F-11-0003, Ver. 3.0

**Purpose of Calculation:**

The purpose of this calculation is to determine the operating range of Farley Nuclear Plant Unit 1 under degraded voltage conditions at the 230kV grid to meet the requirements of the safety-related loads using the guidance in Regulatory Issue Summary RIS 2011-12, Revision 1 (Reference 3). This operating range is used by other calculations to determine Degraded Voltage Relay (DVR) settings to automatically transfer safety-related loads from an unacceptable offsite power source to an onsite power source.

**Summary of Conclusions:**

1. The minimum voltage that meets the steady-state requirements for all safety-related loads during the Normal and LOCA loading cases for Farley Unit 1 is determined, and is documented in Table 1a as the Minimum Required Voltage (MRV). Refer to Attachments 2 and 3 for ETAP output reports.
2. The required starting voltage at the safety-related motors and MOVs is satisfied for the motor starting cases established in calculation SE-94-0470-004 (Design Input 2). Refer to Attachment 4 for ETAP output reports.

3. Some of the safety-related MCCs have voltages below the minimum level required for motor control circuits during the safety injection group motor start; however, per calculation SE-91-1976-1 (Reference 13), these MCCs are acceptable because with the 4kV buses at the MRV, they have the minimum required relay pickup voltage to energize upon an SI signal prior to the motor starting transient. Additionally, load voltages remain above the relay drop-out voltage. See Attachment 1 for motor starting bus voltages.
4. The MRV, shown in Table 1a, is lower than the DVR Lower Analytical Limit (LAL). This LAL is selected to provide margin below the DVR setpoint uncertainty range determined in Design Input 3 and above the MRV. Thus the dropout voltage of each DVR will be set such that the minimum tolerance is above the MRV for the 4160V buses 1F and 1G.
5. The Minimum Expected Voltage (MEV), shown in Table 1a, is higher than the DVR Upper Analytical Limit (UAL). This UAL is selected to provide margin above the DVR setpoint uncertainty range determined in Design Input 3 and below the MEV. Thus the reset voltage of each DVR will be set such that the maximum tolerance is below the MEV for the 4160V buses 1F and 1G.
6. The total available electrical margin available is 1.20% and 1.48% for 4160V buses 1F and 1G, respectively, per the results in Table 1a.
7. The DVR time delay should be set, with tolerances, so that the time is not less than the Safety Injection (SI) Transient Time, and not greater than the minimum thermal overload (TOL) relay trip time, as shown in Table 1b. It is the recommendation of this calculation to set the DVR time delay at 9.0 seconds to keep the safety-related loads on the grid as long as possible while also preventing safety-related motors from tripping due to extended overload conditions. Safety Injection Transient plots are included in Attachment 5, and TOL trip times for SI motors when below the MSV are listed in Attachment 6.
8. Calculations in Attachment 6 indicate that no TOLs will trip prior to the SI Transient Time.
9. The dropout voltage of each LOSP Relay (78.25% per Reference 11) is below the Minimum Starting Voltage (MSV) shown in Table 1a for the 4160V buses 1F and 1G, which occurs immediately after a LOCA group motor start, so there is no expected interaction between the new DVR and the existing LOSP Relay.

**Table 1a. Summary of Unit 1 Degraded Voltage Relay Operating Range Results.**

| 4.16kV Bus | 4.16kV Bus MEV (Attach. 2) | DVR UAL | 4.16kV Bus MRV (Attach. 1) | DVR LAL | 4.16kV Bus MSV | DVR Margin (MEV-MRV) - (UAL-LAL) |
|---|---|---|---|---|---|---|
| 1F | 93.31% | 92.76% | 88.92% | 89.57% | 81.93% | 1.20% |
| 1G | 93.26% | 92.53% | 88.60% | 89.35% | 81.19% | 1.48% |

**Note: All voltages shown in Table 1a are at 4.16kV buses. Voltages at DVRs must account for the PT ratio of 35:1 and a maximum expected voltage drop of 0.12V from secondary of PT to DVR per Attachment 7.

**Table 1b. Summary of Unit 1 DVR Timing Analysis.**

| 4.16kV Bus | SI Transient Start Time (Attach. 5) | TOL Trip Time (Attach. 6) | DVR Trip Setpoint | DVR Time Delay Allowable Value* |
|---|---|---|---|---|
| 1F | 6.5 seconds | 11.5 seconds | 9.0 seconds | ≤ 11.4 seconds |
| 1G | | | | |

* Tech. Spec. DVR Time Setting Requirement

**Methodology:**

The computer model of Farley Unit 1, FNP1V07, was developed with ETAP Version 12.6.0N software package for calculation SE-94-0470-001 (Design Input 1). This calculation uses ETAP software to perform analysis of the auxiliary system including load flow, motor starting, and transient studies. Refer to the ETAP User Guide 12.6 for additional information regarding the ETAP program.

Before the ETAP model was used for this study, outstanding modification calculations (MCs) against base calculation (BC) SE-94-0470-001 (Design Input 1) were merged into the base revision in order of MC approval dates. See Table 2 in the calculation body for a detailed list of merged MCs. The ETAP model was then used to determine several values at the 4kV buses 1F and 1G: the Minimum Expected Voltage, the Minimum Required Voltage, the Minimum Starting Voltage, and the Safety Injection (SI) Transient Time. The methodology for each is described below.

1. Minimum Expected Voltage (MEV): The MEV is calculated as the 4kV bus voltage during LOCA steady-state with a 230kV switchyard voltage of 101.0%. In the Farley Unit 1 ETAP model FNP1V07, this is the Load Flow Study Case 1.4.
2. Minimum Required Voltage (MRV): The MRV is the maximum requirement of the following three calculations.
    a. Using maximum expected non-accident bus loading, determine minimum acceptable steady-state voltage for normal operation of Class 1E loads. This was performed using ETAP load flow study cases 1.3F and 1.3G.
    b. Using maximum expected accident loading, determine the minimum pre-start voltage that provides acceptable Class 1E motor starting (e.g. during LOCA group motor starting). This was performed using ETAP load flow study cases 1.4F and 1.4G.
    c. Using maximum expected accident loading, determine the minimum steady-state voltage that provides acceptable Class 1E motor operation and starting for individual motors. This was performed using ETAP motor starting study cases 4F MOV Start, 4G MOV Start, 5F LOCA Start, 5G LOCA Start, 7F LOCA ST A, and 7G LOCA ST A.
3. Minimum Starting Voltage (MSV): The MSV is calculated as the lowest voltage at the 4kV bus during a safety injection transient (ETAP motor starting study cases 5F LOCA Start and 5G LOCA Start) with the pre-start voltage at the MRV.
4. Safety Injection Transient Time: The SI Transient Time is calculated as the minimum time for the SI group motors to start and reach steady-state with the 4kV buses at the MRV. The ETAP Transient Study Case used to analyze the SI group start is developed as a part of this calculation.

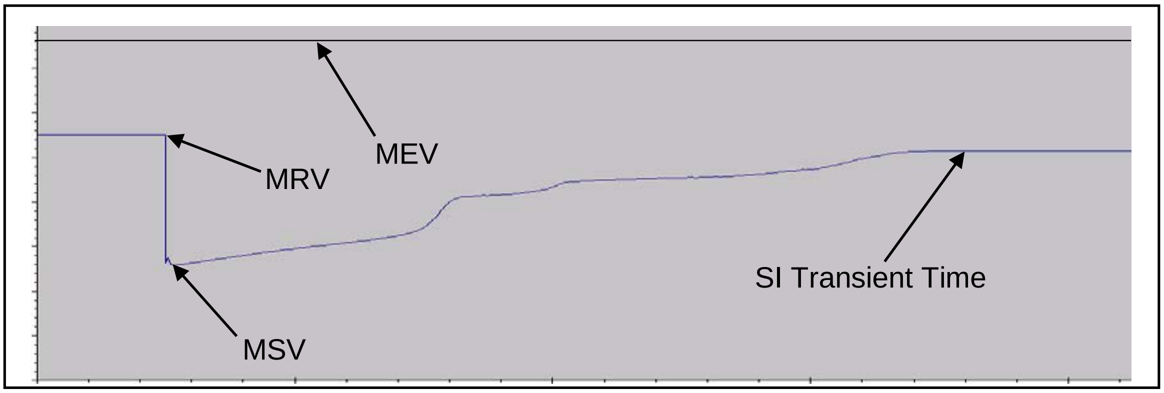



Figure 1. Example SI transient showing location of MEV, MRV, MSV, and SI Transient Time.

The OE search was performed using the following keywords:

- ETAP
- Degraded Grid Relay

| Date | OE Source | Problem | Relevance / Impact | Action / Resolution |
|---|---|---|---|---|
| 11/19/2009 | INPO | **OE30473:** Potential Inaccurate Induction Motor Models in ETAP-Davis-Besse Unit 1:<br>The cumulative load increases due to induction machine modeling techniques may result in non-conservative AC Power System Analyses. For motors operating at greater than 100 percent, allowing efficiency at 100 percent motor load to adjust results in a non-conservative estimate (under prediction) of EDG loading due to the ETAP extrapolation of motor efficiency beyond 100 percent loading. | No motors modeled at greater than 100% loading. | Only applies to older version of ETAP. No action is required. |

**Assumptions:**

1. A minimum expected grid voltage of 101.0% at the 230kV Reference Bus is assumed and utilized in the ETAP model based on contingency studies defined by the FSAR (Reference 6).
2. Loads listed in Attachment 1 with steady-state voltages that do not have motor starting criteria are assumed to be able to endure a transient motor starting situation.
3. Low motor starting voltage for the 3232 MOVs on 600V MCC 1V can be considered acceptable during block starting since the MOVs start with no load. Per SCS Calculation SE-91-1925-14-PE (Reference 14), the maximum load occurs at the end of the close of the stroke when the motors are already running.

4. A constant grid impedance of 0.87+j1.125 percent of 100MVA base is assumed and utilized in the ETAP model per calculation SE-94-0470-001, Attachment C (Design Input 1).
5. ABB 27N calibration limits are determined to be ±0.5 seconds from the Plant Hatch Surveillance Procedure for degraded voltage alarm relays 57SV-S32-002-1, “Emergency Buses 1E, 1F, and 1G Undervoltage Relay Instrument FT&C,” Attachment 3.

**Acceptance Criteria:**

1. The required steady-state voltages at the motor terminals are established in calculation SE-94-0470-004 (Design Input 2). Non-1E motors/loads are allowed to be below 90% rated voltage, since they are not required to mitigate a design basis event.
2. The required starting voltages at the safety-related motors are established in calculation SE-94-0470-004 (Design Input 2). All safety-related motors must be capable of starting at the corresponding MRV.
3. The required MOV starting voltages were established in mechanical torque calculations SM-90-1653-002 (Reference 7), SM-90-1653-009 (Reference 8), and SM-1053039201-001 (Reference 9), as listed in SE-94-0470-004 (Design Input 2). These starting requirements have been updated by DOEJ-FRSNC529029-M001 (Reference 10). All safety-related MOVs must be capable of starting at the corresponding MRV.
4. With the 4kV bus pre-start voltage at the MRV, the SI transient time should be less than the minimum TOL trip time to prevent safety-related equipment from stalling or tripping on overcurrent during a degraded voltage condition.
5. The MRV must be lower than the LAL, and the MEV must be higher than the UAL. The Analytical Limits must be selected to provide margin above and below the setpoint uncertainty range determined in Design Input 3.

**Body of Calculation:**

ETAP was used to simulate normal and accident conditions with a concurrent degraded grid condition. Outstanding MCs and CCNs (References 23-50) against SE-94-0470-001 (Design Input 1) were merged into the ETAP base revision of Farley Unit 1 model FNP1V07 in accordance with Table 2 before any case studies were analyzed. The methodology used in Design Input 1 was followed to set up the ETAP study cases. The 230kV source voltage was modified to obtain the desired voltage at the 4kV bus being studied for each case.

**Table 2. List of Outstanding MCs Merged into ETAP Model Base Revision.**

| MC Number | Approval Date | Merged | Notes |
|---|---|---|---|
| MC-F-06-0143 v1.0 | 9/28/2006 | Yes | |
| MC-F-07-0014 v1.0 | 2/7/2007 | No | Non-conservative |
| MC-F-07-0110 v1.0 | 12/13/2007 | Yes | |
| MC-F-07-0116 v1.0 | 12/13/2007 | Yes | |
| MC-F-08-0076 v1.0 | 6/6/2008 | Yes | |
| MC-F-08-0083 v1.0 | 7/11/2008 | Yes | |
| MC-F-08-0091 v1.0 | 9/15/2008 | Yes | |
| MC-F-08-0162 v1.0 | 11/24/2008 | Yes | |

| | | | |
|---|---|---|---|
| MC-F-08-0194 v1.0 | 12/19/2008 | No | Non-conservative |
| MC-F-08-0017 v3.0 | 5/22/2009 | Yes | |
| MC-F-10-0003 v1.0 | 2/3/2010 | Yes | |
| MC-F-10-0037 v1.0 | 2/10/2010 | Yes | |
| MC-F-10-0005 v1.0 | 2/11/2010 | Yes | |
| MC-F-10-0094 v1.0 | 6/11/2010 | Yes | |
| MC-F-10-0127 v1.0 | 12/7/2010 | Yes | |
| MC-F-08-0026 v1.0 | 12/20/2010 | Yes | |
| MC-F-11-0022 v1.0 | 6/28/2011 | Yes | |
| MC-F-11-0090 v1.0 | 11/9/2011 | Yes | |
| MC-F-12-0002 v1.0 | 3/12/2012 | Yes | |
| CCN-F-11-0003 v3.0 | 8/2/2012 | Yes | |
| MC-F-12-0031 v1.0 | 10/8/2012 | Yes | |
| MC-F-12-0086 v2.0 | 4/11/2013 | Yes | |
| MC-F-11-0077 v1.0 | 4/18/2013 | Yes | |
| MC-F-12-0071 v3.0 | 8/1/2013 | Yes | |
| MC-F-14-0029 v1.0 | 5/5/2014 | No | Non-conservative |
| MC-F-13-0087 v1.0 | 10/15/2014 | Yes | |
| MC-F-07-0050 v2.0 | 10/31/2014 | Yes | |
| MC-F-14-0009 v1.0 | 2/17/2015 | Yes | |
| MC-F-15-0051 v1.0 | 4/9/2015 | No | Non-conservative |

1. Determination of 4kV Minimum Expected Voltage

   The LOCA loading condition, Case 1.4, was performed with the assumed minimum expected 230kV switchyard voltage of 101.0% to establish the minimum expected 4kV bus voltage. This resulted in Minimum Expected Voltages (MEV) of 93.31% for Bus 1F and 93.26% for Bus 1G, as seen in Attachment 1. All safety-related loads had adequate voltage levels for this case.

**Table 3. Minimum Expected 4kV Steady-State Voltage with 230kV Grid at 101%.**

| Train | ETAP Study Case | 230kV Reference Bus Voltage | 4.16kV Min. Expected Voltage (Attach. 3) |
|---|---|---|---|
| 1F | Load Flow Case 1.4 | 101.0% | 93.31% |
| 1G | | | 93.26% |

2. Determination of 4kV Minimum Required Voltage and Minimum Starting Voltages

   Normal steady-state, LOCA steady-state, LOCA group motor starting, and individual motor starting cases were studied to determine the lowest 4kV bus voltage that could supply adequate voltage to all safety-related loads. Based on the existing calculations and the incorporation of outstanding modifications (MCs), the limiting component was found for each train, as summarized in Table 4. Based on the required starting or steady-state voltage of this component, the corresponding pre-start or steady-state voltage at its relative 4kV bus was determined to be the MRV. This MRV was considered for all study cases to verify that all other components achieved adequate voltage to perform the required safety functions. The lowest voltage at the 4kV bus during the LOCA group motor start at the MRV is the MSV (maximum value for the existing LOSP Relay dropout setting).

**Table 4. Minimum Pre-start and Starting Voltages for LOCA Group Start Motors. (See Attachment 1)**

| Train | 4.16kV Bus MRV ($t=0^-$) | 4.16kV Bus MSV ($t=0^+$) | Limiting ETAP Study Case | Limiting Device(s) |
|---|---|---|---|---|
| 1F | 88.92% | 81.93% | Motor Starting 5F LOCA Start | E4 MOV 3024 A, E5 MOV 3024 B |
| 1G | 88.60% | 81.19% | Motor Starting 5G LOCA Start | B4 MOV 2769B, C2 MOV 3478B |

The LOCA safety injection group motor starting scenario was simulated in Case 5F LOCA Start with Bus 1F pre-start voltage forced to the MRV of 88.92%. All safety-related loads fed by Bus 1F maintained adequate starting voltage.

The LOCA motor starting study case 5G LOCA Start was performed with the Bus 1G pre-start voltage forced to the MRV of 88.60%. All safety-related loads fed by Bus 1G maintained adequate starting voltage, except the 3232 MOVs and MOV 3318A on 600V MCC 1V. The 3232 MOVs are acceptable per calculation SE-91-1925-14-PE (Reference 14), as the maximum load occurs at the end of the close of the stroke when the MOVs are already running (see Assumption 3). MOV 3318A would achieve the required voltage by replacement of the thermal overload (TOL) heater with one of a lower resistance.

The post safety injection groups MOV Group A (7F LOCA ST A and 7G LOCA ST A) and MOV Group B (4F MOV START and 4G MOV START) case runs were performed with the 4kV buses forced to their respective MRV. All MOVs in these test groups were capable of starting and maintained adequate terminal voltage.

The normal steady-state cases 1.3F and 1.3G were performed with the 4kV buses forced to their respective MRV. All safety-related loads have positive voltage margin in this scenario.

The LOCA steady-state cases 1.4F and 1.4G were performed with the 4kV buses forced to their respective MRV. All safety-related loads have positive voltage margin in this scenario.

Finally, the individual motor starting cases (4F Individual and 4G Individual) were performed with the 4kV buses forced to their respective MRV. All safety-related loads were capable of starting and maintained adequate terminal voltage.

**Table 5. ETAP Degraded Grid Case Runs in FNP1V07.**

| Configuration | Module | Study Case | Load Cat. | Gen. Cat. | Utility Voltage* |
|---|---|---|---|---|---|
| Case_1.3 | LF | Case 1.3 | Normal | Min-Exp | 101.43% |
| Case_1.3 | LF | Case 1.3F | Normal | DGG-TOL-F | 96.86% |
| Case_1.3 | LF | Case 1.3G | Normal | DGG-TOL-G | 96.18% |
| Case_1.4 | LF | Case 1.4 | LOCA.SS | Min-Exp | 101.45% |
| Case_1.4 | LF | Case 1.4F | LOCA.SS | DGG-F | 97.25% |

| | | | | | |
|---|---|---|---|---|---|
| Case_1.4 | LF | Case 1.4G | LOCA.SS | DGG-G | 97.01% |
| Case_1.4 | MS | 4F MOV Start | LOCA.SS | DGG-F | 97.25% |
| Case_1.4 | MS | 4G MOV Start | LOCA.SS | DGG-G | 97.01% |
| Case_1.4 | MS | 4FIndividual | LOCA.SS | DGG-F | 97.25% |
| Case_1.4 | MS | 4GIndividual | LOCA.SS | DGG-G | 97.01% |
| Case_1.5 | MS | 5F LOCA Strt | LOCA.ST | DGG-F | 96.30% |
| Case_1.5 | MS | 5G LOCA Strt | LOCA.ST | DGG-G | 96.08% |
| Case_1.7 | MS | 7F LOCA ST A | MOV Group A | MOV Grp A-F | 97.22% |
| Case_1.7 | MS | 7G LOCA ST A | MOV Group A | MOV Grp A-G | 96.96% |

*Utility voltage is the ETAP input in percent of 230kV representing the voltage behind the system impedance. Actual 230kV switchyard voltage in each plant configuration and loading category is lower than these values.

Refer to Attachment 1 for a summary of safety-related load voltages and Attachments 2 through 4 for ETAP output results for the case studies shown in Table 5. See Table 6 for a list of motors and MOVs listed in Attachment 1 with less than 0.5% margin between their minimum voltage requirements and their degraded motor starting or steady-state voltages from the above case studies.

**Table 6. Low Degraded Voltage Margin Motors and MOVs per Attachment 1.**

| Motor Name | Case Study | Voltage Req. | Voltage | Margin |
|---|---|---|---|---|
| MOV 8803A | MS 1.5F | 75.30% | 75.78% | 0.48% |
| MOV 3024A | MS 1.5F | 72.87% | 72.87% | 0.00% |
| MOV 3024B | MS 1.5F | 72.87% | 72.87% | 0.00% |
| LCV 0115B | MS 1.5F | 74.96% | 75.42% | 0.46% |
| MOV V516 | MS 1.5G | 75.09% | 75.59% | 0.50% |
| MOV 8803B | MS 1.5G | 68.35% | 68.76% | 0.41% |
| MOV 8100 | MS 1.5G | 68.35% | 68.63% | 0.28% |
| MOV 3232A | MS 1.5G | 73.19% | 71.32% | -1.87%* |
| MOV 3232B | MS 1.5G | 68.02% | 66.29% | -1.73%* |
| MOV 3232C | MS 1.5G | 68.02% | 66.29% | -1.73%* |
| LCV 0115D | MS 1.5G | 68.35% | 68.74% | 0.39% |
| MOV 3318A | MS 1.5G | 70.00% | 69.93% | -0.07%** |
| MOV 2769B | MS 1.5G | 68.65% | 68.65% | 0.00% |
| MOV 3478B | MS 1.5G | 70.41% | 70.41% | 0.00% |
| Ctrl Rm Press Supply Fan B | MS 1.5G | 74.00% | 74.23% | 0.23% |
| Ctrl Rm HVAC Blower 1B | LF 1.4G | 90.00% | 90.12% | 0.12% |
| Ctrl Rm Rad Monitor B | LF 1.3G | 90.00% | 88.31% | -1.69%*** |

*see Assumption 3 for undervoltage justification
**recommended for TOL replacement
***see Attachment 1, Note 6 for undervoltage justification

3. Determination of DVR Time Delay

The safety injection group motors (5F LOCA Start and 5G LOCA Start motors) were modeled in ETAP with available dynamic data from SE-90-1845-2-PE (Reference 12). A transient analysis was performed with the prestart voltage at the 4kV buses set to the MRV. As shown in transient analysis plots in Attachment 5, all SI motors were capable of starting and reaching full speed within 6.5 seconds. Therefore, a DVR time delay of greater than 6.5 seconds is required. In this scenario, if the grid conditions do not recover and the relay does not reset, the DVR is expected to time out and transfer the loads to the diesel generators. In the ETAP transient analysis of the safety injection with the grid at 101%, the 4kV Bus 1F and 1G voltages recover above the MEV faster than the DVR time delay of 6.5 seconds. In this scenario, the DVR would reset, preventing a spurious trip from the offsite power source.

Additionally, during a sustained degraded voltage condition concurrent with a LOCA, the DVR must trip before the diesel generator start time of 12 seconds as specified in the FSAR. The DVR must also trip before any thermal overload (TOL) relays trip from overcurrent. Per Attachment 6, the TOL for LCV0115B has an expected trip time of less than 12 seconds during starting with a voltage below its individual motor starting requirement. MOV TOL trip times were calculated as the average trip time from calculation SE-94-0-0378-001, Attachment 4 (Reference 16) corresponding to the TOL starting multiple calculated per the methodology of SE-94-0-0378-001 multiplied by the MOV's minimum voltage requirement for motor starting (see Attachment 1). TOL trip times for safety-related pumps and fans were calculated similarly in Attachment 6 using data from calculations SE-94-0-0378-001 (Reference 16) and SE-90-1714-12, Attachments 4 and 5 (Reference 18). This timing analysis yields a minimum TOL trip time of 11.5 seconds (at LCV0115B).

$$TOL\ Starting\ Multiple = \frac{LRA * Min.Starting\ Req.}{TOL\ Rating} \xrightarrow{SE-94-0-0378-001} TOL\ Trip\ Time$$

where $TOL\ Rating = 1.25 * Min.TOL\ Selection\ Value\ (amps)$

Note that trip times for overcurrent relays (OCRs) were not considered for the DVR maximum time settings because the 4kV safety injection motors with OCRs are capable of starting at voltages as low as 75%. Below this voltage the existing LOSP Relay should be expected to trip prior to any OCR. See Figure 2 for a visualization of degraded voltage protection.

Given the above constraints, the DVRs must have a time setting between analytical limits of 6.5 seconds and 11.5 seconds. Considering the need to keep safety-related loads on the grid as long as possible while also preventing safety-related motors from tripping due to extended overload conditions, this calculation recommends a setting of 9.0 seconds. Anticipated maximum relay drift is 0.82% of setting per Design Input 3. This yields an upper allowable value for the timing function of ≤11.4 seconds (11.5 sec./100.82%) and a lower allowable value of ≥6.6 seconds (6.5 sec./99.18%). Accounting for calibration tolerances of ±0.5 seconds per Assumption 5 there is sufficient operating range for a setting of 9.0 seconds. Instrument calibration accuracy, radiation, and seismic tolerances are all assumed to be negligible.

| Table 7. DVR Time Delay Operating Range (seconds). | | | | | | |
|---|---|---|---|---|---|---|
| Lower | | | Nominal Trip Setpoint | Upper | | |
| Analytical Limit | Allowable Value | Calib. Limit | | Calib. Limit | Allowable Value* | Analytical Limit |
| 6.5 | ≥ 6.6 | ≥ 8.5 | 9.0 | ≤ 9.5 | ≤ 11.4 | 11.5 |

* Tech. Spec. DVR Time Setting Requirement

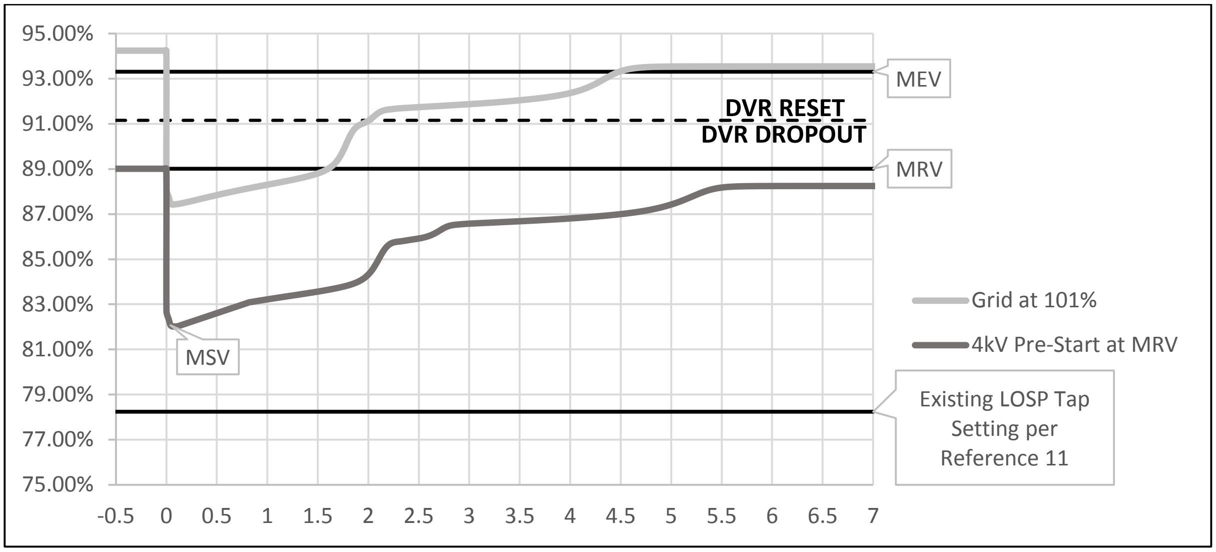



Figure 2. Degraded voltage protection scheme.

**Attachments:**

1. Summary of Steady-State and Starting Voltages at Minimum Required Voltage
2. ETAP Output Reports – NORMAL Load Flow (Configuration Case 1.3)
3. ETAP Output Reports – LOCA Load Flow (Configuration Case 1.4)
4. ETAP Output Reports – Motor Starting (Configuration Cases 1.4, 1.5, and 1.7)
5. Safety Injection Transient Plots
6. Thermal Overload Trip Time Tables
7. AC Voltage Drop from PT to DVR

**Joseph M. Farley Nuclear Plant, Units 1 and 2**
**Technical Specification 3.3.5**
**Loss of Power Diesel Generator Start Instrumentation**
**<u>Supplement to License Amendment Request</u>**

**Enclosure 2**

**FNP Unit 2 Calculation SE-SNC529029-002**
**Minimum Expected Voltage Study**

(Attachments to calculation not included)

SOUTHERN COMPANY
*Energy to Serve Your World®*

**Southern Nuclear Design Calculation**

| Calculation Number: |
|---|
| SE-SNC529029-002 |

| **Plant:** J.M. Farley Nuclear Plant | **Unit:** ☐ 1 ☑ 2 ☐ 1 & 2 | **Discipline:** Electrical |
|---|---|---|
| **Title:** Unit 2 Minimum Expected Voltage Study | | **Subject:** AC System Analysis |
| **Purpose / Objective:** Determine safe operating limits of Unit 2 under degraded grid conditions | | |
| **System or Equipment Tag Numbers:** R01, R11, R15, R16, R17 | | |

**Contents**



**Nuclear Quality Level**

☑ **Safety-Related** ☐ **Safety Significant** ☐ **Non- Safety –Significant**

**Version Record**

| Version No. | Description | Originator Printed Name Initial / Date | Reviewer Printed Name Initial / Date | Approval 1 Printed Name Initial / Date | Approval 2 Printed Name Initial / Date |
|---|---|---|---|---|---|
| 1.0 | Issued per RER SNC529029, v1.0 | Chris Harwell CEH 6/24/15 | Matt Lane ML 6/24/15 | Kevin Littrell KRL 6/24/15 | JOHN MINCEY JEM 6-24-15 |

Notes: An OE search has been performed and the results are documented in the Methodology Section.

**Version History:**

Version 1.0: Initial version issued for RER SNC529029.

**Design Inputs:**

1. SE-94-0470-007, Ver. 7.0, “Unit 2 As-Built Load Study”: Primary calculation input; source of ETAP model and methodology used for case study runs.
2. SE-94-0470-005, Ver. 6.0, “Unit 2 Load Study Summary”: LOCA starting and steady-state requirements tables modified for use as Attachment 1 of this calculation.
3. SJ-SNC529029-001, Ver. 1.0, “Determination Of Setpoints, Reset Points, And Loop Uncertainties For 4160V Safety-Related Degraded Voltage Relay (DVR) Loops (Buses 1F, 2F, 1G And 2G)”

**References:**

1. GDC 17, “General Design Criteria for Nuclear Power Plants 17”
2. IEEE Standard 399-1997, “IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis”
3. NRC Regulatory Issue Summary 2011-12, Revision 1, “Adequacy of Station Electric Distribution System Voltages”: Guidance for degraded grid analysis acceptance criteria and methodology
4. Farley Nuclear Plant Units 1 & 2 Tech Spec Bases, Rev. 66
5. Farley Nuclear Plant Unit 2 Tech Spec, Amendment 193
6. Farley Nuclear Plant Units 1 & 2 FSAR, Rev. 26, March 2015
7. SM-90-1653-002, Ver. 23.0, “Reduced Voltage Torque/Thrust Capability for Gate & Globe Valves in the FNP MOV Program”
8. SM-90-1653-009, Ver. 8.0, “Reduced Voltage Torque Capability for Butterfly Valves in the FNP MOV Program”
9. SM-1053039201-001, Ver. 1.0, “Develop Design Basis Calculations for the Penetration Room Filter Dampers”
10. DOEJ-FRSNC529029-M001, Ver. 1.0, “Evaluation of Reduced Voltage Requirements for Motor Operated Valves for use in the Degraded Voltage Protection Plan”
11. E-035.02.A, Ver. 7.0, “Setting of Protective Relays for 4.16kV Auxiliary Power System”
12. SE-90-1845-2-PE, Ver. 8.0, “Large, Small, and SBO Diesel Dynamic Study”
13. SE-91-1976-1, Ver. 6.0, “Motor Starter Control Circuit Study”
14. SE-91-1925-14-PE, Ver. 1.0, “MOV3232A,B,C: Terminal Voltage at End of Stroke”
15. SE-99-9472-001, Ver. 1.0, “Stability Review for LOSP/DGG Relay Operation”
16. SE-94-0-0378-001, Ver. 5.0, “MOV Combination Starter Component Sizes and Settings”
17. SE-99-0-2010-001, Ver. 0.0, “Verification Package for Computer Software Used to Calculate MOV Thermal Overload Heater Sizes”
18. SE-90-1714-12, Ver. 4.0, “Overload Heater Sizing and Resistance”
19. NEMA MG 1-2003, “Motors and Generators”
20. 1995 SER, February 23, 1995, “Safety Evaluation for Degraded Grid Voltage Relay Set Points”
21. GEH-1768G, “GE Instructions: Undervoltage Relays”
22. MC-F-06-0057, Ver. 1.0
23. MC-F-06-0144, Ver. 1.0

24. MC-F-07-0015, Ver. 1.0
25. MC-F-07-0081, Ver. 1.0
26. MC-F-07-0117, Ver. 1.0
27. MC-F-08-0077, Ver. 1.0
28. MC-F-08-0092, Ver. 1.0
29. MC-F-08-0193, Ver. 1.0
30. MC-F-09-0044, Ver. 1.0
31. MC-F-09-0073, Ver. 1.0
32. MC-F-09-0075, Ver. 1.0
33. MC-F-09-0077, Ver. 1.0
34. MC-F-09-0172, Ver. 1.0
35. MC-F-10-0064, Ver. 1.0
36. MC-F-10-0057, Ver. 1.0
37. MC-F-10-0071, Ver. 1.0
38. MC-F-10-0132, Ver. 2.0
39. MC-F-10-0133, Ver. 1.0
40. MC-F-11-0007, Ver. 1.0
41. MC-F-11-0005, Ver. 1.0
42. MC-F-11-0038, Ver. 1.0
43. MC-F-11-0080, Ver. 1.0
44. MC-F-12-0028, Ver. 1.0
45. MC-F-12-0058, Ver. 1.0
46. MC-F-12-0064, Ver. 1.0
47. MC-F-13-0031, Ver. 1.0
48. MC-F-13-0067, Ver. 1.0
49. MC-F-14-0021, Ver. 1.0
50. CCN-F-13-0001, Ver. 1.0
51. CR 10063545
52. CAR 257139
53. 57SV-S32-002-1, “Emergency Buses 1E, 1F, and 1G Undervoltage Relay Instrument FT&C,” Attachment 3.

**Purpose of Calculation:**

The purpose of this calculation is to determine the operating range of Farley Nuclear Plant Unit 2 under degraded voltage conditions at the 230kV grid to meet the requirements of safety-related loads using the guidance in Regulatory Issue Summary RIS 2011-12, Revision 1 (Reference 3). This operating range is used by other calculations to determine Degraded Voltage Relay (DVR) settings to automatically transfer safety-related loads from an unacceptable offsite power source to an onsite power source.

**Summary of Conclusions:**

1. The minimum voltage that meets the steady-state requirements for all safety-related loads during the Normal and LOCA loading cases for Farley Unit 2 is determined, and is documented in Table 1a as the Minimum Required Voltage (MRV). Refer to Attachments 2 and 3 for ETAP output reports.

2. The required starting voltage at the safety-related motors and MOVs is satisfied for the motor starting cases established in calculation SE-94-0470-005 (Design Input 2). Refer to Attachment 4 for ETAP output reports.
3. Some of the safety-related MCCs have voltages below the minimum level required for motor control circuits during the safety injection group motor start; however, per calculation SE-91-1976-1 (Reference 13), these MCCs are acceptable because with the 4kV buses at the MRV, they have the minimum required relay pickup voltage to energize upon an SI signal prior to the motor starting transient. Additionally, load voltages remain above the relay drop-out voltage. See Attachment 1 for motor starting bus voltages.
4. The MRV, shown in Table 1a, is lower than the DVR Lower Analytical Limit (LAL). This LAL is selected to provide margin below the DVR setpoint uncertainty range determined in Design Input 3 and above the MRV. Thus the dropout voltage of each DVR will be set such that the minimum tolerance is above the MRV for the 4160V buses 2F and 2G.
5. The Minimum Expected Voltage (MEV), shown in Table 1a, is higher than the DVR Upper Analytical Limit (UAL). This UAL is selected to provide margin above the DVR setpoint uncertainty range determined in Design Input 3 and below the MEV. Thus the reset voltage of each DVR will be set such that the maximum tolerance is below the MEV for the 4160V buses 2F and 2G.
6. The total available electrical margin available is 1.54% and 0.99% for 4160V buses 2F and 2G, respectively, per the results in Table 1a.
7. The DVR time delay should be set, with tolerances, so that the time is not less than the Safety Injection (SI) Transient Time, and not greater than the minimum thermal overload (TOL) relay trip time, as shown in Table 1b. It is the recommendation of this calculation to set the DVR time delay at 8.0 seconds to keep the safety-related loads on the grid as long as possible while also preventing safety-related motors from tripping due to extended overload conditions. Safety Injection Transient plots are included in Attachment 5, and TOL trip times for SI motors when below the MSV are listed in Attachment 6.
8. Calculations in Attachment 6 indicate that no TOLs will trip prior to the SI Transient Time.
9. The dropout voltage of each LOSP Relay is below the Minimum Starting Voltage (MSV) shown in Table 1a for the 4160V buses 2F and 2G, which occurs immediately after a LOCA group motor start, so there is no expected interaction between the new DVR and the existing LOSP Relay.

**Table 1a. Summary of Unit 2 Degraded Voltage Relay Operating Range Results.****

| 4.16kV Bus | 4.16kV Bus MEV (Attach. 2) | DVR UAL | 4.16kV Bus MRV (Attach. 1) | DVR LAL | 4.16kV Bus MSV | DVR Margin (MEV-MRV) - (UAL-LAL) |
|---|---|---|---|---|---|---|
| 2F | 93.44% | 92.67% | 88.71% | 89.48% | 81.65% | 1.54% |
| 2G | 93.69% | 93.19% | 89.50% | 89.99% | 82.36% | 0.99% |

**Note: All voltages shown in Table 1a are at 4.16kV buses. Voltages at DVRs must account for the PT ratio of 35:1 and a maximum expected voltage drop of 0.12V from secondary of PT to DVR per Attachment 7.

**Table 1b. Summary of Unit 2 DVR Timing Analysis.**

| 4.16kV Bus | SI Transient Start Time (Attach. 5) | TOL Trip Time (Attach. 6) | DVR Trip Setpoint | DVR Time Delay Allowable Value* |
|---|---|---|---|---|
| 2F | 6.0 seconds | 10.0 seconds | 8.0 seconds | ≤ 9.9 seconds |
| 2G | | | | |

* Tech. Spec. DVR Time Setting Requirement

**Methodology:**

The computer model of Farley Unit 2, FNP2V01, was developed with ETAP Version 12.6.0N software package for calculation SE-94-0470-007 (Design Input 1). This calculation uses ETAP software to perform analysis of the auxiliary system including load flow, motor starting, and transient studies. Refer to the ETAP User Guide 12.6 for additional information regarding the ETAP program.

Version 6.0 of calculation SE-94-0470-007 ETAP model (FNP2V01) was utilized for this calculation. While this study was being finalized, the Unit 2 load study model was also being finalized. Re-analysis utilizing the latest file (FNP2V02) was not required per discussions with SNC.

Before the ETAP model was used for this study, outstanding modification calculations (MCs) against base calculation (BC) SE-94-0470-007 (Design Input 1) were merged into the base revision in order of MC approval dates. See Table 2 in the calculation body for a detailed list of merged MCs. CR 10063545 (Reference 51) was addressed utilizing CAR 257139 (Reference 52) load changes, which were also incorporated into the ETAP model as part of this calculation. The ETAP model was then used to determine several values at the 4kV buses 2F and 2G: the Minimum Expected Voltage, the Minimum Required Voltage, the Minimum Starting Voltage, and the Safety Injection Transient Time (See example of the relationship of these values as shown in Figure 1).

The methodology for each is described below.

1. Minimum Expected Voltage (MEV): The MEV is calculated as the 4kV bus voltage during LOCA steady-state with a 230kV switchyard voltage of 101.0%. In the Farley Unit 2 ETAP model FNP2V01, this is the Load Flow Study Case 2.4.
2. Minimum Required Voltage (MRV): The MRV is the maximum requirement of the following three calculations.
    a. Using maximum expected non-accident bus loading, determine minimum acceptable steady-state voltage for normal operation of Class 1E loads. This was performed using ETAP load flow study cases 2.3F and 2.3G.
    b. Using maximum expected accident loading, determine the minimum pre-start voltage that provides acceptable Class 1E motor starting (e.g. during LOCA group motor starting). This was performed using ETAP load flow study cases 2.4F and 2.4G.
    c. Using maximum expected accident loading, determine the minimum steady-state voltage that provides acceptable Class 1E motor operation and starting for individual motors. This was performed using ETAP motor starting study cases 4F MOV Start, 4G MOV Start, 5F LOCA Start, 5G LOCA Start, 7F LOCA ST A, and 7G LOCA ST A.
3. Minimum Starting Voltage (MSV): The MSV is calculated as the lowest voltage at the 4kV bus during a LOCA group start transient (ETAP motor starting study cases 5F LOCA Start and 5G LOCA Start) with the pre-start voltage at the MRV.
4. Safety Injection Transient Time: The SI Transient Time is calculated as the minimum time for the SI group motors to start and reach steady-state with the 4kV buses at the

MRV. The ETAP Transient Study Case used to analyze the SI group start is developed as a part of this calculation.

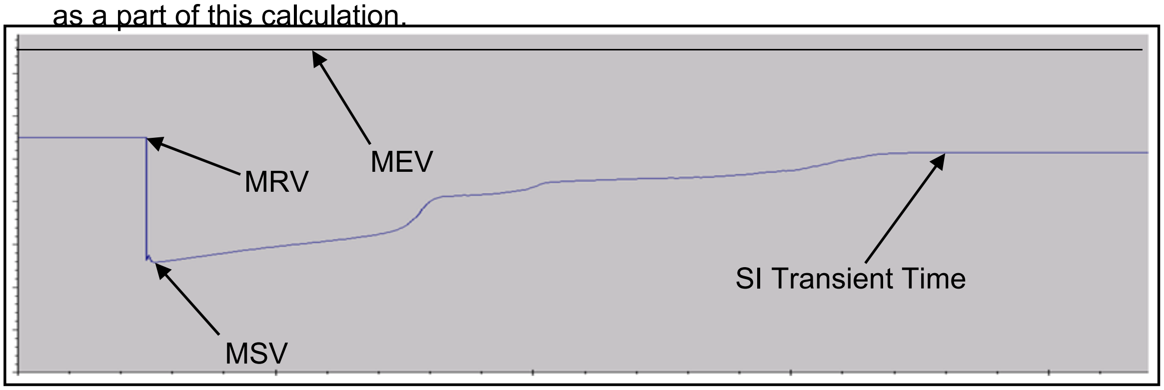



Figure 1. Example SI transient showing location of MEV, MRV, MSV, and SI Transient Time.

The OE search was performed using the following keywords:

- ETAP
- Degraded Grid Relay

| Date | OE Source | Problem | Relevance / Impact | Action / Resolution |
|---|---|---|---|---|
| 11/19/2009 | INPO | **OE30473:** Potential Inaccurate Induction Motor Models in ETAP-Davis-Besse Unit 2:<br>The cumulative load increases due to induction machine modeling techniques may result in non-conservative AC Power System Analyses. For motors operating at greater than 100 percent, allowing efficiency at 100 percent motor load to adjust results in a non-conservative estimate (under prediction) of EDG loading due to the ETAP extrapolation of motor efficiency beyond 100 percent loading. | No motors modeled at greater than 100% loading. | Only applies to older versions of ETAP. No action is required. |

**Assumptions:**

1. A minimum expected grid voltage of 101.0% at the 230kV Reference Bus is assumed and utilized in the ETAP model based on contingency studies defined by the FSAR (Reference 6).
2. Loads listed in Attachment 1 with steady-state voltages that do not have motor starting criteria are assumed to be able to endure a transient motor starting situation.
3. Low motor starting voltage for the 3232 MOVs on 600V MCC 2V can be considered acceptable during block starting since the MOVs start with no load. Per SCS Calculation

SE-91-1925-14-PE (Reference 14), the maximum load occurs at the end of the close of the stroke when the motors are already running.

4. A constant grid impedance of 0.87+j1.125 percent of 100MVA base is assumed and utilized in the ETAP model per calculation SE-94-0470-007, Attachment C (Design Input 1).
5. ABB 27N calibration limits are determined to be ±0.5 seconds from the Plant Hatch Surveillance Procedure for degraded voltage alarm relays 57SV-S32-002-1, "Emergency Buses 1E, 1F, and 1G Undervoltage Relay Instrument FT&C," Attachment 3 (Reference 53).

**Acceptance Criteria:**

1. The required steady-state voltages at the motor terminals are established in calculation SE-94-0470-005 (Design Input 2). Non-1E motors/loads are allowed to be below 90% rated voltage, since they are not required to mitigate a design basis event.
2. The required starting voltages at the safety-related motors are established in calculation SE-94-0470-005 (Design Input 2). All safety-related motors must be capable of starting at the corresponding MRV.
3. The required MOV starting voltages are established in mechanical torque calculations SM-90-1653-002 (Reference 7), SM-90-1653-009 (Reference 8) and SM-1053039201-001 (Reference 9), as listed in SE-94-0470-005 (Design Input 2). These starting requirements have been updated by DOEJ-FRSNC529029-M001 (Reference 10). All safety-related MOVs must be capable of starting at the corresponding MRV.
4. With the 4kV bus pre-start voltage at the MRV, the SI transient time should be less than the minimum TOL trip time to prevent safety-related equipment from stalling or tripping on overcurrent during a degraded voltage condition.
5. The MRV must be lower than the LAL, and the MEV must be higher than the UAL. The Analytical Limits must be selected to provide margin above and below the setpoint uncertainty range determined in Design Input 3.

**Body of Calculation:**

ETAP was used to simulate normal and accident conditions with a concurrent degraded grid condition. Outstanding MCs and CCNs (References 22-50) against SE-94-0470-007 (Design Input 1) were merged into the ETAP base revision of Farley Unit 2 model FNP2V01 in accordance with Table 2 before any case studies were analyzed. The methodology used in Design Input 1 was followed to set up the ETAP study cases. The 230kV source voltage was modified to obtain the desired voltage at the 4kV bus being studied for each case.

**Table 2. List of Outstanding MCs Merged into ETAP Model Base Revision.**

| MC Number | Approval Date | Merged | Notes |
|---|---|---|---|
| MC-F-06-0057 v1.0 | 3/22/2006 | No | Removes load |
| MC-F-06-0144 v1.0 | 9/28/2006 | Yes | |
| MC-F-07-0015 v1.0 | 2/07/2007 | No | Removes load |
| MC-F-07-0081 v1.0 | 3/11/2008 | Yes | |
| MC-F-07-0117 v1.0 | 12/13/2007 | Yes | |

| Table 2. List of Outstanding MCs Merged into ETAP Model Base Revision. | | | |
| --- | --- | --- | --- |
| **MC Number** | **Approval Date** | **Merged** | **Notes** |
| MC-F-08-0092 v1.0 | 9/15/2008 | Yes | |
| MC-F-08-0077 v1.0 | 6/6/2008 | Yes | |
| MC-F-08-0193 v1.0 | 12/19/2008 | No | Removes load |
| MC-F-09-0044 v1.0 | 3/23/2009 | Yes | |
| MC-F-09-0073 v1.0 | 7/30/2009 | Yes | Merged because MDC is as-built |
| MC-F-09-0075 v1.0 | 7/30/2009 | Yes | MDC is closed, but not yet closed by site |
| MC-F-09-0077 v1.0 | 7/30/2009 | Yes | Merged because MDC is as-built |
| MC-F-09-0172 v1.0 | 12/30/2009 | Yes | |
| MC-F-10-0064 v1.0 | 4/13/2010 | Yes | MDC is closed, but not yet closed by site |
| MC-F-10-0071 v1.0 | 6/13/2010 | Yes | |
| MC-F-10-0057 v1.0 | 6/13/2010 | Yes | |
| MC-F-10-0133 v1.0 | 12/7/2010 | Yes | |
| MC-F-11-0007 v1.0 | 2/21/2011 | No | Reduces load |
| MC-F-11-0005 v1.0 | 3/10/2011 | Yes | MDC is closed, but not yet closed by site |
| MC-F-10-0132 v2.0 | 8/17/2011 | Yes | |
| MC-F-11-0038 v1.0 | 10/12/2011 | Yes | |
| MC-F-12-0028 v1.0 | 10/8/2012 | Yes | |
| MC-F-12-0064 v1.0 | 2/7/2013 | Yes | |
| CCN-F-13-0001 v1.0 | 3/5/2013 | Yes | |
| MC-F-11-0080 v1.0 | 4/18/2013 | Yes | |
| MC-F-13-0031 v1.0 | 9/5/2013 | No | Removes load |
| MC-F-14-0021 v1.0 | 11/7/2014 | Yes | |
| MC-F-12-0058 v1.0 | 12/18/2014 | Yes | |
| MC-F-13-0067 v1.0 | 2/9/2015 | Yes | |

1. Determination of 4kV Minimum Expected Voltage

   The LOCA loading condition, Case 2.4, was performed with the assumed minimum expected 230kV switchyard voltage of 101.0% to establish the minimum expected 4kV bus voltage. This resulted in minimum expected 4kV voltages (MEV) of 93.44% for Bus 2F and 93.69% for Bus 2G, as seen in Attachment 1. All safety-related loads had adequate voltage levels for this case.

| Table 3. Minimum Expected 4kV Steady-State Voltage with 230kV Grid at 101%. | | | |
| --- | --- | --- | --- |
| **Train** | **ETAP Study Case** | **230kV Reference Bus Voltage** | **4.16kV Min. Expected Voltage (Attach. 3)** |
| 2F | Load Flow Case 2.4 | 101.0% | 93.44% |
| 2G | | | 93.69% |

2. Determination of 4kV Minimum Required Voltage and Minimum Starting Voltages

Normal steady-state, LOCA steady-state, LOCA group motor starting, and individual motor starting cases were studied to determine the lowest 4kV bus voltage that could supply adequate voltage to all safety-related loads. Based on the existing calculations and the incorporation of outstanding modifications (MCs), the limiting component was found for each train, as summarized in Table 4. Based on the required starting or steady-state voltage of this component, the corresponding pre-start or steady-state voltage at its relative 4kV bus was determined to be the MRV. This MRV was considered for all study cases to verify that all other components achieved adequate voltage to perform the required safety functions. The lowest voltage at the 4kV bus during the LOCA group motor start at the MRV is the MSV (maximum value for the LOSP Relay dropout setting).

**Table 4. Minimum Pre-start and Starting Voltages for LOCA Group Start Motors. (See Attachment 1)**

| Train | 4.16kV Bus MRV ($t=0^-$) | 4.16kV Bus MSV ($t=0^+$) | Limiting ETAP Study Case | Limiting Device |
|---|---|---|---|---|
| 2F | 88.71% | 81.65% | Motor Starting 5F LOCA Start | B3 Serv Wtr MOV 515 B4 Serv Wtr MOV 517 |
| 2G | 89.50% | 82.36% | Motor Starting 5G LOCA Start | B4 MOV 2769B, C2 MOV 3478B |

The LOCA safety injection group motor starting scenario was simulated in case 5F LOCA Start with Bus 2F pre-start voltage forced to the MRV of 88.71%. All safety-related loads fed by Bus 2F maintained adequate starting voltage.

The LOCA safety injection group motor starting scenario was simulated in case 5G LOCA Start with Bus 2G pre-start voltage forced to the MRV of 89.50%. All safety-related loads fed by Bus 2G maintained adequate starting voltage, except the 3232 MOVs on 600V MCC 2V. The 3232 MOVs are acceptable per calculation SE-91-1925-14-PE (Reference 14), as the maximum load occurs at the end of the close of the stroke when the MOVs are already running (see Assumption 3).

The post safety injection groups MOV Group A (7F LOCA ST A and 7G LOCA ST A) and MOV Group B (4F MOV START and 4G MOV START) case runs were performed with the 4kV buses forced to their respective MRV. All MOVs in these test groups were capable of starting and maintained adequate terminal voltage.

The normal steady-state cases 2.3F and 2.3G were performed with the 4kV buses forced to their respective MRV. All safety-related loads have positive voltage margin in this scenario.

The LOCA steady-state cases 2.4F and 2.4G were performed with the 4kV buses forced to their respective MRV. All safety-related loads have positive voltage margin in this scenario.

Finally, the individual motor starting cases (4F Individual and 4G Individual) were performed with the 4kV buses forced to their respective MRV. All safety-related loads were capable of starting and maintained adequate terminal voltage.

**Table 5. ETAP Degraded Grid Case Runs in FNP2V01.**

| Configuration | Module | Study Case | Load Cat. | Gen. Cat. | Utility Voltage* |
|---|---|---|---|---|---|
| Case_2.3 | LF | Case 2.3 | Normal | Min-Exp | 101.40% |
| Case_2.3 | LF | Case 2.3F | Normal | DGG-TOL-F | 96.25% |
| Case_2.3 | LF | Case 2.3G | Normal | DGG-TOL-G | 96.63% |
| Case_2.4 | LF | Case 2.4 | LOCA.SS | Min-Exp | 101.43% |
| Case_2.4 | LF | Case 2.4F | LOCA.SS | DGG-F | 96.90% |
| Case_2.4 | LF | Case 2.4G | LOCA.SS | DGG-G | 97.40% |
| Case_2.4 | MS | 4F MOV Start | LOCA.SS | DGG-F | 96.90% |
| Case_2.4 | MS | 4G MOV Start | LOCA.SS | DGG-G | 97.40% |
| Case_2.4 | MS | 4FIndividual | LOCA.SS | DGG-F | 96.90% |
| Case_2.4 | MS | 4GIndividual | LOCA.SS | DGG-G | 97.40% |
| Case_2.5 | MS | 5F LOCA Strt | LOCA.ST | DGG-F | 95.95% |
| Case_2.5 | MS | 5G LOCA Strt | LOCA.ST | DGG-G | 96.48% |
| Case_2.7 | MS | 7F LOCA ST A | MOV Grp A | MOV Grp A-F | 96.70% |
| Case_2.7 | MS | 7G LOCA ST A | MOV Grp A | MOV Grp A-G | 97.23% |

*Utility voltage is the ETAP input in percent of 230kV representing the voltage behind the system impedance. Actual 230kV switchyard voltage in each plant configuration and loading category is lower than these values.

Refer to Attachment 1 for a summary of safety-related load voltages and Attachments 2 through 4 for ETAP output results for the case studies shown in Table 5. See Table 6 for a list of motors and MOVs listed in Attachment 1 with less than 0.5% margin between their minimum voltage requirements and their degraded motor starting or steady-state voltages from the above case studies.

**Table 6. Low Degraded Voltage Margin Motors and MOVs per Attachment 1.**

| Motor Name | Case Study | Voltage Req. | Voltage | Margin |
|---|---|---|---|---|
| MOV 3478A | MS 2.5F | 75.99% | 76.41% | 0.42% |
| MOV 2769A | MS 2.5F | 73.93% | 74.34% | 0.41% |
| MOV V515 | MS 2.5F | 84.86% | 84.86% | 0.00% |
| MOV V517 | MS 2.5F | 84.86% | 84.86% | 0.00% |
| MOV 8811A | MS 2.4F MOV | 78.78% | 78.95% | 0.17% |
| Solatron Voltage Reg. | LF 2.4F | 77.00% | 77.10% | 0.10% |
| Mult Relay Cab 1A | LF 2.4F | 88.19% | 88.41% | 0.22% |
| MOV 3024C | MS 2.5G | 65.57% | 65.85% | 0.28% |
| MOV 3024D | MS 2.5G | 66.09% | 66.69% | 0.60% |
| MOV 8100 | MS 2.5G | 68.70% | 68.94% | 0.24% |
| MOV 3232A | MS 2.5G | 72.05% | 71.28% | -0.76%* |
| MOV 3232B | MS 2.5G | 72.57% | 71.56% | -1.01%* |
| MOV 3232C | MS 2.5G | 73.24% | 72.48% | -0.76%* |
| MOV 3318A | MS 2.5G | 70.00% | 71.74% | 1.74% |
| MOV V516 | MS 2.5G | 75.21% | 75.40% | 0.19% |

| Table 6. Low Degraded Voltage Margin Motors and MOVs per Attachment 1. | | | | |
|---|---|---|---|---|
| **Motor Name** | **Case Study** | **Voltage Req.** | **Voltage** | **Margin** |
| MOV 2769B | MS 2.5G | 68.65% | 68.65% | 0.00% |
| MOV 3478B | MS 2.5G | 70.41% | 70.41% | 0.00% |
| Ctrl Rm Press Supply Fan B | MS 2.5G | 74.00% | 74.23% | 0.23% |
| Ctrl Rm Rad Monitor | LF 2.3G | 90.00% | 90.39% | 0.39% |
| L5L Spent Fuel Pool Mon. | LF 2.4G | 90.00% | 90.46% | 0.46% |

*see Assumption 3 for justification for negative margin

3. Determination of DVR Time Delay

The safety injection group motors (5F LOCA Start and 5G LOCA Start motors) were modeled in ETAP with available dynamic data from SE-90-1845-2-PE (Reference 12). A transient analysis was performed with the prestart voltage at the 4kV buses set to the MRV. As shown in transient analysis plots in Attachment 5, all SI motors were capable of starting and reaching full speed within 6 seconds. Therefore, a DVR time delay of greater than 6 seconds is required. In this scenario, if the grid conditions do not recover and the relay does not reset, the DVR is expected to time out and transfer the loads to the diesel generators. In the ETAP transient analysis of the safety injection with the grid at 101%, the 4kV Bus 2F and 2G voltages recover above the MEV faster than the DVR time delay of 6 seconds. In this scenario, the DVR would reset, preventing a spurious trip from the offsite power source.

Additionally, during a sustained degraded voltage condition concurrent with a LOCA, the DVR must trip before the diesel generator start time of 12 seconds as specified in the FSAR. The DVR must also trip before any thermal overload (TOL) relays trip from overcurrent. Per Attachment 6, TOLs for five MOVs have expected trip times of less than 12 seconds during starting with a voltage below their individual motor starting requirement. MOV TOL trip times were calculated as the average trip time from calculation SE-94-0-0378-001, Attachment 4 (Reference 16) corresponding to the TOL starting multiple calculated per the methodology of SE-94-0-0378-001 multiplied by the MOV's minimum voltage requirement for motor starting (see Attachment 1). TOL trip times for safety-related pumps and fans were calculated similarly in Attachment 6 using data from calculations SE-94-0-0378-001 (Reference 16) and SE-90-1714-12, Attachments 4 and 5 (Reference 18). This analysis yields a minimum TOL trip time of 10 seconds (at MOV 3232B).

$$TOL\ Starting\ Multiple = \frac{LRA * Min.Starting\ Req.}{TOL\ Rating} \xrightarrow{SE-94-0-0378-001} TOL\ Trip\ Time$$

where $TOL\ Rating = 1.25 * Min.TOL\ Selection\ Value\ (amps)$

Note that trip times for overcurrent relays (OCRs) were not considered for the DVR maximum time settings because the 4kV safety injection motors with OCRs are capable of starting at voltages as low as 75%. Below this voltage the LOSP Relay should be expected to trip prior to any OCR. See Figure 2 for a visualization of degraded voltage protection.

Given the above constraints, the DVRs must have a time setting between analytical limits of 6.0 seconds and 10.0 seconds. Considering the need to keep safety-related loads on the grid as long as possible while also preventing safety-related motors from tripping due to extended overload conditions, this calculation recommends a setting of 8.0 seconds. Anticipated maximum relay drift is 0.82% of setting per Design Input 3. This yields an upper allowable value for the timing function of ≤9.9 seconds (10.0 sec./100.82%) and a lower allowable value of ≥6.1 seconds (6.0 sec./99.18%). Accounting for calibration tolerances of ±0.5 seconds per Assumption 5 there is sufficient operating range for a setting of 8.0 seconds. Instrument calibration accuracy, radiation, and seismic tolerances are all assumed to be negligible.

**Table 7. DVR Time Delay Operating Range (seconds).**

| Lower | | | Nominal | Upper | | |
|---|---|---|---|---|---|---|
| Analytical Limit | Allowable Value | Calib. Limit | Trip Setpoint | Calib. Limit | Allowable Value* | Analytical Limit |
| 6.0 | ≥ 6.1 | ≥ 7.5 | 8.0 | ≤ 8.5 | ≤ 9.9 | 10.0 |

* Tech. Spec. DVR Time Setting Requirement

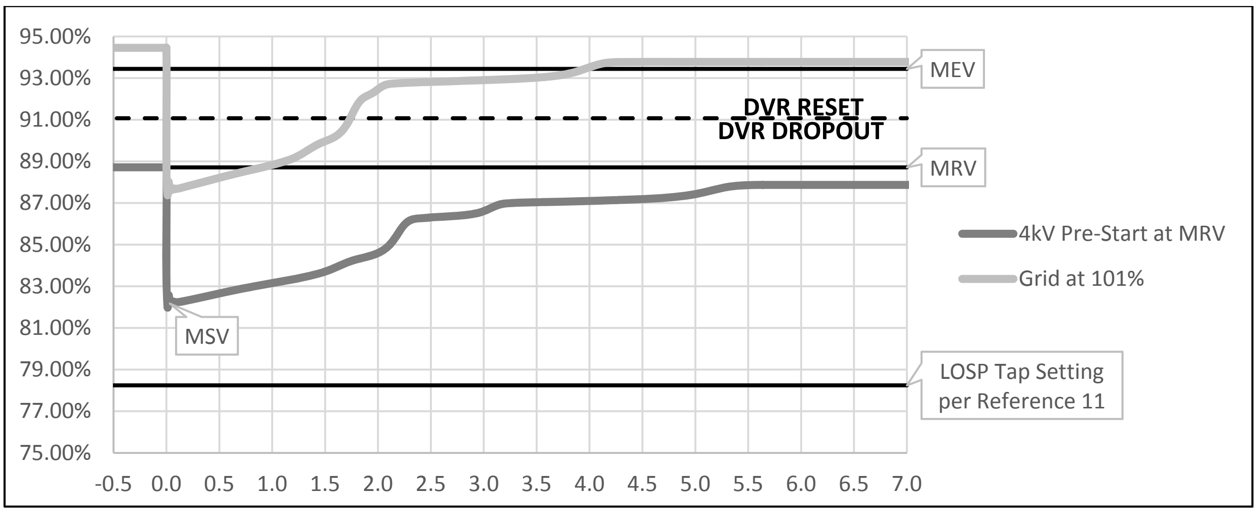



Figure 2. Degraded voltage protection scheme.

**Attachments:**

1. Summary of Steady-State and Starting Voltages at Minimum Required Voltage
2. ETAP Output Reports – NORMAL Load Flow (Configuration Case 2.3)
3. ETAP Output Reports – LOCA Load Flow (Configuration Case 2.4)
4. ETAP Output Reports – Motor Starting (Configuration Cases 2.4, 2.5, and 2.7)
5. Safety Injection Transient Plots
6. Thermal Overload Trip Time Table
7. AC Voltage Drop from PT to DVR

**Joseph M. Farley Nuclear Plant, Units 1 and 2**
**Technical Specification 3.3.5**
**Loss of Power Diesel Generator Start Instrumentation**
**<u>Supplement to License Amendment Request</u>**

**Enclosure 3**

**FNP Units 1 & 2 Calculation SJ-SNC529029-001**
**Determination of Setpoints**

(Attachments to calculation not included)

Southern Nuclear Design Calculation

SOUTHERN COMPANY
Energy to Serve Your World

| Calculation Number: |
|---|
| SJ-SNC529029-001 |

| Plant: Farley | Unit: ☐ 1 ☐ 2 ☒ 1 & 2 | Discipline: I&C |
|---|---|---|
| **Title:** Determination Of Setpoints, Reset Points And Loop Uncertainties For The 4160V Safety-Related Degraded Voltage Relay (DVR) Loops (Buses 1F, 2F, 1G And 2G) | | **Subject:** 4160 KV Buses 1F, 1G, 2F & 2G Degraded Voltage Relays |
| **Purpose / Objective:** Determine available margin | | |
| **System or Equipment Tag Numbers:** 27F3 (3-1), 27F3 (2-3), 27F3 (1-2); 27G3 (3-1), 27G3 (2-3), 27G3 (1-2) | | |

**Contents**



**Nuclear Quality Level**

☒ Safety-Related ☐ Safety Significant ☐ Non- Safety –Significant

**Version Record**

| Version No. | Description | Originator Printed Name Initial / Date | Reviewer Printed Name Initial / Date | Approval 1 Printed Name Initial / Date | Approval 2 Printed Name Initial / Date |
|---|---|---|---|---|---|
| 1 | Issued | Mary Coffaro MQC 4-28-15 | Robin Smith RS 4/28/15 | Kevin Littrell KRL 4/30/15 | John Minley [illegible] 6-24-15 |
| | | | | | |

Note: An OE search has been performed and the results are documented in the Methodology section on page 5.

1.0 Purpose

The purpose of this calculation is to determine the limiting allowable values, setpoints, reset points, available margin and loop uncertainties for the undervoltage function of the 4160V safety-related degraded voltage relay (DVR) loops (Buses 1F, 2F, 1G and 2G). The DVR relays used in this application have an integral user-settable time delay function. This calculation addresses the undervoltage function of the relay only. The timing function of the relays is address in calculations SE-SNC529029-001 (Reference 4) and SE-SNC529029-002 (Reference 8).

2.0 Summary of Conclusions:

The limiting allowable values, setpoints, reset points, loop uncertainties and margins for the undervoltage function of the 4160V safety-related DVR loops (Buses 1F, 2F, 1G and 2G) are reflected in tables 1a and 1b below.

**Table 1a - Allowable Values, Nominal Setpoints and Uncertainties (Undervoltage Function)**
**Refer to Figure 1, page 3 for illustrative presentation of Limiting Values**

| Under-voltage Function | Allowable Value | | Nominal Setpoint | | Loop Uncertainty in % 120VAC | Loop Uncertainty (VAC) at secondary |
|---|---|---|---|---|---|---|
| | At Primary VAC (%4160V) | At Relay VAC | At Primary VAC (%4160V) | At Relay VAC | | |
| **Bus 1F** **Upper (Reset)[b]:** | ≤3831.80[a] (92.11) | ≤109.36 | 3808.00 (91.54) | 108.68 | 1.11 | 1.33 |
| **Lower (Trip):** | ≥3760.75[a] (90.40) | ≥107.45 | 3784.55 (90.97) | 108.13 | 1.11 | 1.33 |
| **Bus 1G** **Upper (Reset)[b]:** | ≤3822.00[a] (91.88) | ≤109.08 | 3798.20 (91.30) | 108.40 | 1.11 | 1.33 |
| **Lower (Trip):** | ≥3751.65[a] (90.18) | ≥107.19 | 3775.10 (90.75) | 107.86 | 1.10 | 1.32 |
| **Bus 2F** **Upper (Reset)[b]:** | ≤3827.95[a] (92.02) | ≤109.25 | 3804.15 (91.45) | 108.57 | 1.11 | 1.33 |
| **Lower (Trip):** | ≥3757.25[a] (90.32) | ≥107.35 | 3780.70 (90.88) | 108.02 | 1.10 | 1.32 |
| **Bus 2G** **Upper (Reset)[b]:** | ≤3849.30[a] (92.53) | ≤109.86 | 3825.50 (91.96) | 109.18 | 1.12 | 1.34 |
| **Lower (Trip):** | ≥3778.25[a] (90.82) | ≥107.95 | 3802.05 (91.40) | 108.63 | 1.11 | 1.33 |

NOTES:

a) Technical Specification Table 3.3.5-1.2 “Loss of Power Diesel Generator Start Instrumentation” recommended Allowable Value

b) Upper value at primary side (Vp) adjusted to reflect 0.12V voltage drop on the secondary side (cable between the PT and DVR).

The calculated setpoint and allowable values account for an additional margin of 0.22 VAC on the secondary side of the PT (120 VAC buses).

## Figure 1 – Limiting Values Diagram[2]

| | VAC at primary (Vp) | (VAC at relay) (Vr) |
|---|---|---|
| Upper AL | 3858.82 (92.76%) | (110.13) |
| **Technical Specification Upper Allowable Value** | **3831.80**[1] | **(109.36)** |
| Reset Upper Calibration Limit | 3812.20[1] | (108.80) |
| **Nominal Reset Setpoint** | **3808.00**[1] | **(108.68)** |
| Reset Lower Calibration Limit | 3803.80[1] | (108.56) |
| Setpoint Upper Calibration Limit | 3788.75 | (108.25) |
| **Nominal Setpoint** | **3784.55** | **(108.13)** |
| Setpoint Lower Calibration Limit | 3780.35 | (108.01) |
| **Technical Specification Lower Allowable Value** | **3760.75** | **(107.45)** |
| Lower AL | 3726.11 (89.57%) | (106.47) |

**Notes:**

1. Value adjusted for 0.12 voltage drop on the secondary side (cable between the PT and DVR).
2. Bus 1F is shown. Buses 1G, 2F and 2G are similar.

## 3.0 Discussion of Methodology

Due to the simple configuration of this loop and the use of components traditionally not found in instruments loops, there are very few uncertainty terms that apply to this calculation. The loop consists of a potential transformer and an undervoltage relay with an integral user-settable time delay function. The uncertainties associated with the undervoltage function for the relays listed below are addressed in this calculation:

| Bus 1F | Bus 1G | Bus 2F | Bus 2G |
|---|---|---|---|
| Q1R43E0001A27F312 | Q1R43E0001B27G312 | Q2R43E0001A27F312 | Q2R43E0001B27G312 |
| Q1R43E0001A27F323 | Q1R43E0001B27G323 | Q2R43E0001A27F323 | Q2R43E0001B27G323 |
| Q1R43E0001A27F331 | Q1R43E0001B27G331 | Q2R43E0001A27F331 | Q2R43E0001B27G331 |

Due to the functional nature of this loop, the enhanced uncertainty methodology in section A.4.3 of DI-2 is followed as a guideline only. Vendor-provided uncertainty terms are in % setting. Therefore, where necessary, the upper and lower uncertainty terms are derived separately. These terms are prefixed by a “U” and “L” respectively.

The following discussion addresses the justification and assumptions used in determining the applicable uncertainty terms and the channel statistical allowance (CSA) equation.

Each DVR loop consists of a transformer and relay. In order to use terminology consistent with DI-2, for the purposes of this calculation the transformer will be treated as the primary element and the relay as the rack comparator (bistable) instrument. There is no sensor in this loop. The pressure effects normally associated with the sensor will be considered in the calculation of the rack uncertainties (RPE term). Therefore the CSA is defined for this two element loop as:

$$\mathrm{CSA} = \sqrt{(\mathrm{RD} + \mathrm{RMTE})^2 + (\mathrm{RCSA} + \mathrm{RMTE})^2 + \mathrm{RRA}^2 + \mathrm{RTE}^2 + \mathrm{RPE}^2 + \mathrm{PEA}^2 + \mathrm{PMA}^2} + (BIAS + EA)$$

For this application: RCSA and RMTE are considered dependent variables. RRA, RTE, RPE and PEA are considered independent variables with respect to RCSA and RMTE and each other.

RD is not combined with any other term since it is derived from plant data which includes any contributions associated with other error terms including RMTE. Therefore the following equation is used to calculate CSA:

$$\mathrm{CSA} = \pm[(\mathrm{RCSA}+\mathrm{RMTE})^2 + (\mathrm{RRA})^2 + (\mathrm{RTE})^2 + (\mathrm{RPE})^2 + (\mathrm{RD})^2 + (\mathrm{PEA})^2]^{1/2}$$

This calculation takes into consideration the voltage drop between the secondary side of the PT and the DVR. The voltage at the DVR shall be designated as Vr. The voltage at the secondary side of the PT shall be designated as Vs and the voltage at the primary side of the PT shall be designated as Vp.

An iterative method is used to determine the drop out (trip) setpoint (LNTSP), pickup (reset) setpoint (UNTSP) and margin (upper and lower) for the undervoltage function. The goal is to determine a setpoint/reset such that lower margin is 0.2% setting and the upper margin is

0.0% setting. The process is as follows (the specific numbers provided below are based on Bus 1F, Table 5):

From DI-4, Table 1a, the upper analytical limit is 92.76% 4160V. This equates to 3858.82V on the primary side (Vp) and 110.25V on the secondary side (Vs) of the transformer. The analytical limit on the secondary side of the transformer is then adjusted to account for a 0.12V voltage drop on the cable between the PT and DVR (assumption 8). Therefore, for the purposes of this calculation the upper analytical limit used for calculating the DVR setpoints is 110.13V (110.25V – 0.12V) at the relay (Vr). From DI-4, Table 1a, the lower analytical limit is 89.57% 4160V. This equates to 3726.11V on the primary side (Vp) and 106.47V on the secondary side (Vs) of the transformer.

A value is chosen for the dropout setpoint (108.13V). Using the formulas from NMP-ES-033-004, the relay uncertainty (LCSA) is determined (1.32V). Then the lower margin (LM) is determined (0.22V). From these derived values, the dropout setpoint at the lower calibration limit is verified to determine that it will support the lower analytical limit without excess margin. In essence, this means the value for the dropout setpoint minus the relay uncertainty (LCSA) of 1.32V and lower margin (LM) of 0.22V does not fall below the analytical limit. The dropout setpoint at the lower calibration limit is 108.01V (108.13V – 0.12V). Therefore, for bus 1F: 108.01V – 1.32V – 0.22V ≥ 106.47V.

After the dropout setpoint at the lower calibration limit is verified, the drift value (LRD) of 0.80V is determined for derivation of the lower Allowable Value. The lower Allowable Value is derived by subtracting the drift from the upper calibration limit of the dropout setpoint. The dropout setpoint at the upper calibration limit is 108.25V (108.13V + 0.12V). This lower Allowable Value (LAV) is 107.45V (108.25V - 0.80V).

Once all the values for the dropout setpoint, lower Allowable Value and the dropout calibration limits are determined, then the pickup or reset setpoint needs to be determined. Design Engineering has requested that the pickup setpoint be as small as possible. For this model of relay, a potentiometer is used to set the difference between the dropout and the pickup setpoints. The smallest difference between the two setpoints is 0.5% of the dropout setting. Therefore, the minimum pickup setpoint is 100.5% of the dropout nominal setting of 108.13V. This value equates to 108.68V (108.13 * 100.5%).

At this point, the same process used for determining the lower settings is used to determine the upper settings, adding the UCSA to the upper calibration limit to verify a margin of 0% against the upper analytical limit at the relay (Vr) and adding URD to the lower calibration limit to determine an upper Allowable Value (UAV) of 109.36V.

Following this process, the calibration limits for bus 1F were determined to be:

108.01V and 108.25V (108.13V ±0.12V) for the dropout setpoint and

108.56V and 108.80V (108.68V ±0.12V) for the pickup or reset setpoint.

This methodology provides a margin of 0.20% setting for the dropout function and 0% setting for the pickup (reset) function.

An OE search was performed using the following keywords:
Degraded Grid Relay, Harmonic Filter, Harmonic Restraint, ABB 27N, DVR Relay and DVR

The results are as follows:

**Table 2 - OE Search Results**

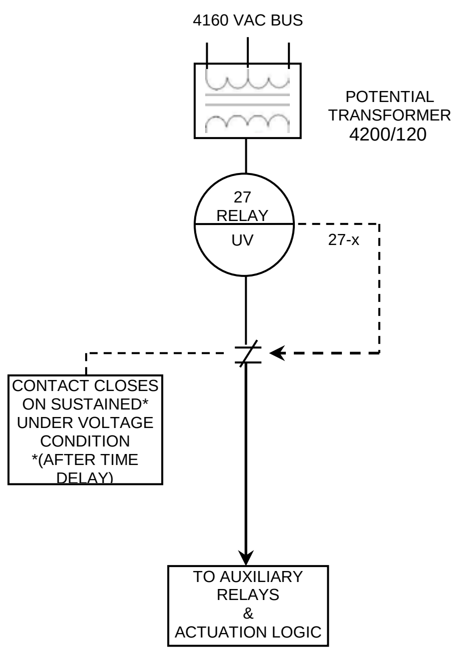
| OE Source | Potential Project Impact: | Relevance/Impact |
|---|---|---|
| LER 92-012-00 (Hatch) | On 3/31/92, with the reactor shutdown for routine refueling and maintenance, the Electrical Maintenance Department found the setpoints of four degraded grid undervoltage relays (EIIS=EB) to be below their technical specification limits. This condition was identified while performing normal surveillance activities associated with emergency busses three and four. The cause of the event is attributed to setpoint drift outside of an extremely tight tolerance band. The relays were reset to within their proper tolerance band. | The setting tolerance used in the calculation for the undervoltage function of the relays is assumed to be equal to the worst case reference accuracy of ±0.12 VAC (0.1%*120VAC). The drift allowance used is based on plant historical data for ABB 27N degraded voltage relays used in a similar application at a plant with similar operating conditions and calibration practices. This should allow for adequate tolerance between the limiting technical specification NTSPs and AVs. |
| O&MR 225 | During calibration of the 4160V 'D' and 'E' bus undervoltage relay system, the setpoints for three ITE model 27H relays in 4160V bus '1E' were found out of tolerance. Plants using ITE model 27H relays in their undervoltage protection systems should check them for unacceptable setpoint drift. The supplier, Brown Boveri, advises that ITE model 27N relays should be used for this application. | The relays used for this application are the Brown Boveri recommended 27N models. |
| SEN 272 | The bus ground fault protection relay, 50G/A52-84, actuated and isolated power to the bus. The 50G relay spuriously operated in response to the fault condition; but the cause, although not fully conclusive, is suspected to be high-frequency energy from the ground fault. The high-frequency current flow through the cable capacitance-to-ground reached sufficient magnitudes to actuate the 50G relay. The 50G relay on 1B-04 is a solid-state design and was set at 10 amperes, the lower end of the range (10 to 50 amps) per generic industry guidance. The companion 50G/1A52-58 relay on the other safeguards train, 1B-03, is an older style electromechanical relay and was also | The settings chosen for the relays provide sufficent margin betweenthe lower and upper range limits to avoid spurious actuations. |

| OE Source | Potential Project Impact: | Relevance/Impact |
|---|---|---|
| | set at the low end of the 2.5 to 5 amperes range. The station replaced the 50G/A52-84 train B relay. The settings of both relays were increased to approximately midrange within the acceptable bands. The 50G/A52-84 relay setting was raised from 10 amperes to 30 amperes to reduce the potential for spurious trips. The companion 50G/1A52-58 relay setting on safeguards train 1B-03 was raised to 3 amperes. The solid state design relays are within IEEE generic guidance. No guidance was located for the older electromechanical design relays. | |

4.0 Functional Description

The undervoltage relays monitor voltage on 4160 VAC emergency buses 1F, 1G, 2F and 2G (three relays per bus) and actuate when the voltage falls below a predetermined value and remains below this value for a specified amount of time. Actuation of any two out of three relays on the same bus results in an automatic trip of the applicable 4160 VAC preferred power supply breakers, disconnecting the undervoltage (degraded) bus from its offsite preferred power source. The degraded grid voltage and time settings are selected to avoid any nuisance tripping during normal operating conditions while ensuring that the voltage requirements of the safety-related loads are met without exceeding the maximum time delay assumed in the safety analyses.

**Figure 2 - Loop Configuration**



5.0 Body of Calculation

Sensor TPNS Tag #: 4160V Bus 1F Relays: 27F3 (3-1), 27F3 (2-3), 27F3 (1-2)
4160V Bus 1G Relays: 27G3 (3-1), 27G3 (2-3), 27G3 (1-2)
4160V Bus 2F Relays: 27F3 (3-1), 27F3 (2-3), 27F3 (1-2)
4160V Bus 2G Relays: 27G3 (3-1), 27G3 (2-3), 27G3 (1-2)

Manufacturer: Asea Brown Boveri (ABB) Model 27N411T5375-HF
PM: Once every 18 months
Location of Sensor: Auxiliary Building

| Environmental/Seismic Conditions | Normal | Design | Calibration |
|---|---|---|---|
| **Temperature** | 80°F | 110°F | 70°F |
| **Pressure** | N/A | N/A | N/A |
| **Humidity** | N/A | N/A | N/A |

Assumptions

1. Accuracy specifications provided in DI-1 for the undervoltage function are based on the specific operating temperature and control power range applicable to the relays. All accuracies are in % setting and are as follows:

   Pickup and dropout settings, repeatability (RRA): ±0.1% at constant temperature and voltage
   Pickup and dropout settings, repeatability (TE): ± 0.75% over a temperature range of 0 to +55°C (32 to 131°F)
   Pickup and dropout settings, repeatability (PSE): ±0.1% over a control power range of 100 to 140 VDC (125VDC nominal)

   The vendor specifies that these tolerances may be cumulative. Therefore, these variables will be considered interactive for the purposes of this calculation.

2. The relays are solid state devices whose accuracy is not affected by the expected normal auxiliary building pressure and humidity. Therefore, pressure effect (RPE) and humidity effect (HE) are not applicable for the undervoltage function.
   RPE = HE = 0.

3. Based on section 2.4 of attachment 1 to DI-2, the average temperature for the auxiliary building is 80°F and the design limit of the auxiliary building room ambient temperature is 110°F. The minimum temperature expected in the rooms in which the relays are located is 60°F (Reference DI-16). Therefore, for this application the temperature range is assumed to be 60°F to 110°F.

4. The calibration tolerance (RCSA) for the undervoltage function trip and reset is assumed to be equal to the worst case reference accuracy of ±0.12 VAC (0.1%*120VAC).

5. A Fluke 8600A (200 VAC) is assumed to be used to read the voltage input when calibrating the voltage function of the relays. Per DI-2, attachment 2 the accuracy of a Fluke 8600A is 0.2% of input + 0.015% of range. Therefore, instrument calibration accuracy (RMTE) is equal to 0.2% of setting + 0.03 VAC for the undervoltage function.

6. The vendor does not specify a drift value for the undervoltage function and no plant historical data is available on the ABB 27N relays. However, there are ABB 27N relays

used at the E. I. Hatch Nuclear Plant in a similar application. A drift analysis was performed on the calibration data available from these relays (Attachment A). The various factors that can contribute to variations in the drift performance between the two plants (Hatch and Farley) are compared and evaluated in the following table.

**Table 3 – Evaluated Drift Factors**

| Item | Factor | Analyzed relays (E.I Hatch) | Farley application | Discussion |
|---|---|---|---|---|
| **1** | **Calibration Span** | NA | NA | The 27N relays are bistable devices. |
| **2** | **Operating Environment*** | 50 to 105°F (Reference DI-9) | 60 to 110°F, average temperature 80°F (Reference Assumption 3, DI-15 & DI-16) | The upper limit indicated for this application is the design limit. Based on the average temperature of the relays of 80°F, it is reasonable to assume that the actual temperature in the area will not exceed 105°F. Therefore, for the purpose of this analysis the operating temperature of the analyzed relays envelops the operating temperature of the relays being used for this application and this parameter is not a factor in applying the calculated drift values to the new relays. |
| **3** | **Calibration Practice** | Per DI-13 & DI-14 | The same or better (Assumption 16 & 17) | No adverse variation in calibration practices. Therefore, calibration practice is not a factor in applying the calculated drift values to the new relays. |
| **4** | **Calibration Check Point** | Setpoint/reset point (nominal) Voltage: 109 to 111/110 to 112 VAC<br>(Reference DI-13 & DI-14) | Setpoint/reset point (nominal) Voltage: 107.86 to 108.63/108.40 to 109.18 VAC<br>(Derived in this calculation) | The undervoltage setpoint/reset points of the two plants are reasonably close (within 3.4%) and therefore, the calibration check point difference is not considered a factor in applying the calculated drift values to the new relays. |
| **5** | **Calibration Interval** | Analyzed for 18 month interval | Same (18 month extended to 22.5 month) | N/A |
| **6** | **Human Performance** | See discussion | See discussion | The technicians performing the calibrations are assumed to have commensurate skills and experience. Therefore, human performance is not a factor. |

| Item | Factor | Analyzed relays (E.I Hatch) | Farley application | Discussion |
|---|---|---|---|---|
| **7** | **Instrument Age** | See discussion | See discussion | Age-dependent drift is the tendency for instrument drift to trend as the instrument ages. A review of the data in Attachment A does not indicate any drift trend as the relay aged. Therefore, instrument age is not a consideration for this application. |

*Variations in pressure and humidity are assumed to have no effect on the relay (Assumption 2).

Based on the above evaluation it is reasonable to assume that the undervoltage function drift is equal to the drift value derived in Attachment A for a 22.5 month interval of 0.53% setting (rounded from 0.5265% setting) with no significant bias. However, for conservatism, a drift value of 0.73% setting shall be used in this calculation.

7. Per DI-3, the potential transformers for buses 1F, 1G, 2F, 2G are loaded such that a 0.3% accuracy applies (PEA). Therefore, PEA = 0.3%.

8. The maximum voltage drop on the cables from the PTs to the DVRs is calculated in Attachment 7 of DI-4 and 8 as 0.12 V. This value is subtracted from the 120 VAC upper analytical limit (Vs) to determine the actual upper analytical limits at the relays (Vr) and added to the derived upper (reset) relay settings to determine the voltage on the primary side of the transformers (Vp). For conservatism, the voltage drop is not applied to the lower analytical limit.

9. The primary to secondary voltage ratio of the transformer is 35:1 (4200VAC:120VAC).

10. The test source used in calibrating the relays has less than 0.3% harmonic distortion.

11. Radiation and seismic effects (RE and SE) are assumed to be negligible (zero).

12. The relays are operated within the vendor specified parameters for temperature (-22 to +158°F) (Reference DI-1); therefore, temperature effects (TE) for the undervoltage function are as specified in assumption 1.

13. The revised voltage analytical limits are based on plant modifications as described in DI-4 and DI-8.

14. The control power at the relays is assumed to be within the vendor specified parameters of 100 – 140 VDC. This is based on DI-5, which specifies that the maximum voltage of the battery chargers which supply power to the relays is 132 VDC ±0.5% (132.66 VDC). The minimum voltage at the relays occurs when the relays are being powered by the emergency batteries only. DI-6 and DI-7 indicate that this voltage does not fall below the lower limitation (100 VDC) of the relays. Therefore, power supply effects (PSE) for the undervoltage function are as specified in assumption 1.

15. The drift uncertainty is time dependent and non-linear and can be extrapolated using the square root of the sum of the squares (SRSS) method per section 6.2.7 of Reference 1.

16. The maintenance and test equipment (M&TE) used for the calibration of the Farley degraded voltage relays will be equivalent or better than the M&TE equipment used to calibrate the Hatch degraded grid ABB 27N alarm relays identified in Attachment A.

17. The calibration methodology used for the Farley degraded voltage relays will be the same methodology used to calibrate the Hatch degraded grid ABB 27N alarm relays (see assumption 6, Attachment A and section 7.5 of DI-13 & DI-14).

Buses 1F, 1G, 2F and 2G Undervoltage Function:

**Table 4 – Derivation of Uncertainties (Undervoltage Function)**

| PARAMETER | JUSTIFICATION | UNCERTAINTY VALUE (% SETTING) |
|---|---|---|
| RRA | RRA = ±0.10% SETTING (Assumption 1) | ±0.10 |
| RMTE | A Fluke 8600A (200 VAC) will be used to calibrate the undervoltage function of the relays (Assumption 5)<br>RMTE = ±0.2% SETTING + 0.03 VAC<br>$= \pm 0.2 + \frac{(0.03*100)}{\text{SETTING}}$ % SETTING<br>$= \pm(0.2 + \frac{3.0}{\text{SETTING}})$ % SETTING | $\pm 0.2 + \frac{3.0}{\text{SETTING}}$ |
| RD | RD = ±0.73% SETTING (Assumption 6) | ±0.73 |
| RCSA | RCSA = ±0.12 VAC (Assumption 4)<br>$= \pm\frac{(0.12\text{ VAC}*100)}{\text{SETTING}} * (\%\text{ SETTING})$<br>$= \pm(\frac{12.0}{\text{SETTING}})$ % SETTING | $\pm\frac{12.0}{\text{SETTING}}$ |
| RTE | $RTE = \pm((TE + PSE)^2 + HE^2 + RE^2)^{1/2}$<br>(Assumptions 1, 2, 11)<br>$= \pm(0.75 + 0.1)^2 + 0^2 + 0^2)^{1/2}$ % SETTING<br>= ±0.85% SETTING | ±0.85 |
| RPE | RPE = 0.0 VAC (Assumption 2)<br>$= \pm\frac{(0.0\text{ VAC} * 100)}{\text{SETTING}}$ % SETTING<br>= ±0.0% SETTING | ±0.0 |
| Relay Reset Differential (RSM) | RSM = 0.5% SETTING (Reference DI-1) | 0.5 |

Process Allowances:

| | | |
|---|---|---|
| PEA | Process Parameter Tag #:<br>4160V Bus 1F 4200/120 VAC Transformers:<br>PT-1, PT-2, PT-3<br>4160V Bus 1G 4200/120 VAC Transformers:<br>PT-1, PT-2, PT-3<br>4160V Bus 2F 4200/120 VAC Transformers:<br>PT-1, PT-2, PT-3<br>4160V Bus 2G 4200/120 VAC Transformers:<br>PT-1, PT-2, PT-3<br>Description: primary element<br>Description of PEA: transformer<br><br>PEA = ±0.3% full scale (Assumption 7)<br>$= \pm (\frac{(0.3 * 120\text{ VAC})}{100} * \frac{(100)}{\text{SETTING}}$ % SETTING<br>$= \pm \frac{(36.0)}{\text{SETTING}}$ % SETTING | $\pm\frac{36.0}{\text{SETTING}}$ |

| | | |
|---|---|---|
| PMA | PMA does not apply to transformers. Therefore, PMA = N/A | N/A |

Bias:

| | | |
|---|---|---|
| EA | The cables, transformers and relays are not exposed to a harsh environment. Therefore, EA = N/A. (Reference DI-15) | N/A |
| Bias | No bias terms exist for this loop. Therefore, Bias = N/A | N/A |

Therefore, based on the equation derived in section 3.0:

$$CSA = \pm [(RCSA+RMTE)^2 + (RRA)^2 + (RTE)^2 + (RPE)^2 + (RD)^2 + (PEA)^2]^{1/2}$$

$$CSA = \pm\left\{\left(\frac{12.0}{SETTING} + 0.2 + \frac{3.0}{SETTING}\right)^2 + (0.10)^2 + (0.85)^2 + (0)^2 + (0.73)^2 + \left(\frac{36.0}{SETTING}\right)^2\right\}^{1/2} \text{ \% SETTING}$$

$$= \pm\left\{\left(\frac{15.0}{SETTING} + 0.2\right)^2 + 0.01 + 0.7225 + 0.5329 + \frac{1296}{(SETTING)^2}\right\}^{1/2} \text{ \% SETTING}$$

$$= \pm\left\{\frac{225}{(SETTING)^2} + \frac{6.0}{SETTING} + 0.04 + 0.01 + 0.7225 + 0.5329 + \frac{1296}{(SETTING)^2}\right\}^{1/2} \text{ \% SETTING}$$

$$= \pm\left\{\frac{1521}{(SETTING)^2} + \frac{6.0}{SETTING} + 1.3054\right\}^{1/2} \text{ \% SETTING}$$

The Analytical Limits for the undervoltage function of the DVRs are as follows:

**Bus 1F**

Upper Analytical Limit (UAL) = 92.76% of 4160VAC at primary (Reference DI-4, Table 1a)
= (0.9276*4160) VAC at primary
= 3858.82 VAC at primary (Vp)
= (0.9276*4160)/35 – 0.12 VAC at relay (Assumption 8)
= 110.13 VAC at relay (Vr)

Lower Analytical Limit (LAL) = 89.57% of 4160VAC at primary (Reference DI-4, Table 1a)
= (0.8957*4160) VAC at primary
= 3726.11 VAC at primary (Vp)
= (0.8957*4160)/35 at secondary/relay (Assumption 8)
= 106.47 VAC at secondary/relay (Vs,Vr)

**Bus 1G**

Upper Analytical Limit (UAL) = 92.53% of 4160VAC at primary (Reference DI-4, Table 1a)
= (0.9253*4160) VAC at primary
= 3849.25 VAC at primary (Vp)
= (0.9253*4160)/35 – 0.12 VAC at relay (Assumption 8)
= 109.85 VAC at relay (Vr)

Lower Analytical Limit (LAL) = 89.35% of 4160VAC at primary (Reference DI-4, Table 1a)
= (0.8935*4160) VAC at primary
= 3716.96 VAC at primary (Vp)
= (0.8935*4160)/35 at secondary/relay (Assumption 8)
= 106.20 VAC at secondary/relay (Vs,Vr)

**Bus 2F**

Upper Analytical Limit (UAL) = 92.67% of 4160VAC at primary (Reference DI-8, Table 1a)
= (0.9267*4160) VAC at primary
= 3855.07 VAC at primary (Vp)
= (0.9267*4160)/35 – 0.12 VAC at relay (Assumption 8)
= 110.02 VAC at relay (Vr)

Lower Analytical Limit (LAL) = 89.48% of 4160VAC at primary (Reference DI-8, Table 1a)
= (0.8948*4160) VAC at primary
= 3722.37 VAC at primary (Vp)
= (0.8948*4160)/35 at secondary/relay (Assumption 8)
= 106.36 VAC at secondary/relay (Vs,Vr)

**Bus 2G**

Upper Analytical Limit (UAL) = 93.19% of 4160VAC at primary (Reference DI-8, Table 1a)
= (0.9319*4160) VAC at primary
= 3876.70 VAC at primary (Vp)
= (0.9319*4160)/35 – 0.12 VAC at relay (Assumption 8)
= 110.64 VAC at relay (Vr)

Lower Analytical Limit (LAL) = 89.99% of 4160VAC at primary (Reference DI-8, Table 1a)
= (0.8999*4160) VAC at primary
= 3743.58 VAC at primary (Vp)
= (0.8999*4160)/35 at secondary/relay (Assumption 8)
= 106.96 VAC at secondary/relay (Vs,Vr)

The values calculated in the following tables are based on the methodology outlined in DI-2, section A.3.45 and presented as shown in DI-2, Appendix B page 52.

**Table 5 – Bus 1F Calculation of Limiting Values (Undervoltage Function)**

| | | At Reset Point | | Reset Point at Upper Calibration Limit | | Reset Point at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| Upper Analytical Limit (UAL) **(Vr) | | 110.13 | 91.78 | 110.13 | 91.78 | 110.13 | 91.78 |
| Upper Margin (UM) | | 0.12 | 0.10 | 0.00 | 0.00 | 0.24 | 0.20 |
| Adjusted UAL (UAL-UM) | | 110.01 | 91.68 | 110.13 | 91.78 | 109.89 | 91.58 |
| Upper Allowable Value (UAV) = UCLL + URD | | | | | | 109.36 | 91.13 |
| URD | 0.73 | | | | | 0.80 | 0.67 |
| UCSA | [1521/SETTING$^2$ + 6.0/SETTING +1.3054]$^{1/2}$ | 1.33 | 1.11 | 1.33 | 1.11 | 1.33 | 1.11 |
| UCLH (Upper Calibration Limit - High) TS RSP = UNTSP + RCSA | | | | **108.80*** | 90.67 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Upper Nominal Reset Point (UNTSP) *pickup* | | **108.68*** | 90.57 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| UCLL (Upper Calibration Limit - Low) = UNTSP - RCSA | | | | | | **108.56*** | 90.47 |

| | | At Setpoint (Proposed Relay Setting) | | Setpoint at Upper Calibration Limit | | Setpoint at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| LCLH (Lower Calibration Limit - High) = LNTSP + RCSA | | | | **108.25*** | 90.21 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Lower Nominal Trip Setpoint (LNTSP) *dropout* | | **108.13*** | 90.11 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| LCLL (Lower Calibration Limit – Low) TS SP = LNTSP – RCSA | | | | | | **108.01*** | 90.01 |
| LCSA | [1521/SETTING$^2$ + 6.0/SETTING +1.3054]$^{1/2}$ | 1.33 | 1.11 | 1.33 | 1.11 | 1.32 | 1.10 |
| LRD | 0.73 | | | 0.80 | 0.67 | | |
| Lower Allowable Value (LAV) = setting value - LRD | | | | 107.45 | 89.54 | | |
| Adjusted LAL (LAL + LM) | | 106.80 | 89.00 | 106.92 | 89.10 | 106.69 | 88.91 |
| Lower Margin (LM) | | 0.33 | 0.27 | 0.45 | 0.38 | 0.22 | 0.18 |
| Lower Analytical Limit (LAL) (Vs) | | 106.47 | 88.73 | 106.47 | 88.73 | 106.47 | 88.73 |

* Indicates setting value used to calculate AV, RCSA and CSA for each section outlined in the Table

** Adjusted for voltage drop of 0.12V at secondary (Assumption 8)

**Bus 1F Undervoltage Function:**

Based on Table 5 the limiting settings for the undervoltage function for Bus 1F are as follows:

Upper Allowable Value (reset point) = 109.36 VAC (91.13% 120VAC) increasing at relay (Vr)
= (109.36 VAC + 0.12) * 35 = 3831.80 VAC increasing at primary (Assumption 8) (Vp)
= (3831.80/4160) * 100% = 92.11% 4160VAC increasing at primary

Nominal Reset point = 108.68 VAC (90.57% 120VAC) increasing at relay (Vr)
= (108.68 VAC + 0.12) * 35 = 3808.00 VAC increasing at primary (Assumption 8) (Vp)
= (3808.00/4160) * 100% = 91.54% 4160VAC increasing at primary

Nominal Setpoint = 108.13 VAC (90.11% 120VAC) decreasing at secondary (Vs, Vr)
= 108.13 VAC * 35 = 3784.55 VAC decreasing at primary (Vp)
= (3784.55/4160) * 100% = 90.97% 4160VAC decreasing at primary

Lower Allowable Value (setpoint) = 107.45 VAC (89.54% 120VAC) decreasing at secondary (Vs, Vr)
= 107.45 VAC * 35 = 3760.75 VAC decreasing at primary (Vp)
= (3760.75/4160) * 100% = 90.40% 4160VAC decreasing at primary

This allows for a minimum margin of 0.22 VAC (0.20% of the lower calibration limit of 108.01 VAC).

**Table 6 – Bus 1G Calculation of Limiting Values (Undervoltage Function)**

| | | At Reset Point | | Reset Point at Upper Calibration Limit | | Reset Point at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| Upper Analytical Limit (UAL) ** (Vr) | | 109.85 | 91.54 | 109.85 | 91.54 | 109.85 | 91.54 |
| Upper Margin (UM) | | 0.12 | 0.10 | 0.00 | 0.00 | 0.24 | 0.20 |
| Adjusted UAL (UAL-UM) | | 109.73 | 91.44 | 109.85 | 91.54 | 109.61 | 91.34 |
| Upper Allowable Value (UAV) = UCLL + URD | | | | | | 109.08 | 90.90 |
| URD | 0.73 | | | | | 0.80 | 0.67 |
| UCSA | $[1521/SETTING^2 + 6.0/SETTING + 1.3054]^{1/2}$ | 1.33 | 1.11 | 1.33 | 1.11 | 1.33 | 1.11 |
| UCLH (Upper Calibration Limit - High) TS RSP = UNTSP + RCSA | | | | **108.52*** | 90.43 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Upper Nominal Reset Point (UNTSP) *pickup* | | **108.40*** | 90.33 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| UCLL (Upper Calibration Limit - Low) = UNTSP - RCSA | | | | | | **108.28*** | 90.23 |

| | | At Setpoint (Proposed Relay Setting) | | Setpoint at Upper Calibration Limit | | Setpoint at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| LCLH (Lower Calibration Limit - High) = LNTSP + RCSA | | | | **107.98*** | 89.98 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Lower Nominal Trip Setpoint (LNTSP) *dropout* | | **107.86*** | 89.88 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| LCLL (Lower Calibration Limit – Low) TS SP = LNTSP – RCSA | | | | | | **107.74*** | 89.78 |
| LCSA | $[1521/SETTING^2 + 6.0/SETTING + 1.3054]^{1/2}$ | 1.32 | 1.10 | 1.32 | 1.10 | 1.32 | 1.10 |
| LRD | 0.73 | | | 0.79 | 0.66 | | |
| Lower Allowable Value (LAV) = setting value - LRD | | | | 107.19 | 89.33 | | |
| Adjusted LAL (LAL + LM) | | 106.54 | 88.78 | 106.66 | 88.88 | 106.42 | 88.68 |
| Lower Margin (LM) | | 0.34 | 0.28 | 0.46 | 0.38 | 0.22 | 0.18 |
| Lower Analytical Limit (LAL) (Vs) | | 106.20 | 88.50 | 106.20 | 88.50 | 106.20 | 88.50 |

* Indicates setting value used to calculate AV, RCSA and CSA for each section outlined in the Table

** Adjusted for voltage drop of 0.12V at secondary (Assumption 8)

**Bus 1G Undervoltage Function:**

Based on Table 6 the limiting settings for the undervoltage function for Bus 1G are as follows:

Upper Allowable Value (reset point) = 109.08 VAC (90.90% 120VAC) increasing at relay (Vr)
= (109.08 VAC + 0.12) * 35 = 3822.00 VAC increasing at primary (Assumption 8) (Vp)
= (3822.00/4160) * 100% = 91.88% 4160VAC increasing at primary

Reset point = 108.40 VAC (90.33% 120VAC) increasing at relay (Vr)
= (108.40 VAC + 0.12) * 35 = 3798.20 VAC increasing at primary (Assumption 8) (Vp)
= (3798.20/4160) * 100% = 91.30% 4160VAC increasing at primary

Setpoint = 107.86 VAC ((89.88% 120VAC) decreasing at secondary (Vs, Vr)
= 107.86 VAC * 35 = 3775.10 VAC decreasing at primary (Vp)
= (3775.10/4160) * 100% = 90.75% 4160VAC decreasing at primary

Lower Allowable Value (setpoint) = 107.19 VAC (89.33% 120VAC) decreasing at secondary (Vs, Vr)
= 107.19 VAC * 35 = 3751.65 VAC decreasing at primary (Vp)
= (3751.65/4160) * 100% = 90.18% 4160VAC decreasing at primary

This allows for a minimum margin of 0.22 VAC (0.20% of the lower calibration limit of 107.74 VAC).

## Table 7– Bus 2F Calculation of Limiting Values (Undervoltage Function)

| | | At Reset Point | | Reset Point at Upper Calibration Limit | | Reset Point at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| Upper Analytical Limit (UAL) ** (Vr) | | 110.02 | 91.68 | 110.02 | 91.68 | 110.02 | 91.68 |
| Upper Margin (UM) | | 0.12 | 0.10 | 0.00 | 0.00 | 0.24 | 0.20 |
| Adjusted UAL (UAL-UM) | | 109.90 | 91.58 | 110.02 | 91.68 | 109.78 | 91.48 |
| Upper Allowable Value (UAV) = UCLL + URD | | | | | | 109.25 | 91.04 |
| URD | 0.73 | | | | | 0.80 | 0.67 |
| UCSA | [1521/SETTING$^2$ + 6.0/SETTING +1.3054]$^{1/2}$ | 1.33 | 1.11 | 1.33 | 1.11 | 1.33 | 1.11 |
| UCLH (Upper Calibration Limit - High) TS RSP = UNTSP + RCSA | | | | **108.69*** | 90.58 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Upper Nominal Reset Point (UNTSP) *pickup* | | **108.57*** | 90.48 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| UCLL (Upper Calibration Limit – Low) = UNTSP – RCSA | | | | | | **108.45*** | 90.38 |

| | | At Setpoint (Proposed Relay Setting) | | Setpoint at Upper Calibration Limit | | Setpoint at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| LCLH (Lower Calibration Limit - High) = LNTSP + RCSA | | | | **108.14*** | 90.12 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Lower Nominal Trip Setpoint (LNTSP) *dropout* | | **108.02*** | 90.02 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| LCLL (Lower Calibration Limit – Low) TS SP = LNTSP – RCSA | | | | | | **107.90*** | 89.92 |
| LCSA | [1521/SETTING$^2$ + 6.0/SETTING +1.3054]$^{1/2}$ | 1.32 | 1.10 | 1.33 | 1.11 | 1.32 | 1.10 |
| LRD | 0.73 | 0.79 | 0.66 | 0.79 | 0.66 | 0.79 | 0.66 |
| Lower Allowable Value (LAV) = setting value - LRD | | | | 107.35 | 89.46 | | |
| Adjusted LAL (LAL + LM) | | 106.70 | 88.92 | 106.81 | 89.01 | 106.58 | 88.82 |
| Lower Margin (LM) | | 0.34 | 0.28 | 0.45 | 0.38 | 0.22 | 0.18 |
| Lower Analytical Limit (LAL) (Vs) | | 106.36 | 88.63 | 106.36 | 88.63 | 106.36 | 88.63 |

* Indicates setting value used to calculate AV, RCSA and CSA for each section outlined in the Table

** Adjusted for voltage drop of 0.12V at secondary (Assumption 8)

**Bus 2F Undervoltage Function:**

| | |
|---|---|
| Upper Allowable Value (reset point) | = 109.25 VAC (91.04% 120VAC) increasing at relay (Vr)<br>= (109.25 VAC + 0.12) * 35 = 3827.95 VAC increasing at primary (Assumption 8) (Vp)<br>= (3827.95/4160) * 100% = 92.02% 4160VAC increasing at primary |
| Reset point | = 108.57 VAC (90.48% 120VAC) increasing at relay (Vr)<br>= (108.57 VAC+ 0.12) * 35 = 3804.15 VAC increasing at primary (Assumption 8) (Vp)<br>= (3804.15/4160) * 100% = 91.45% 4160VAC increasing at primary |
| Setpoint | = 108.02 VAC (90.02% 120VAC) decreasing at secondary (Vs, Vr)<br>= 108.02 VAC * 35 = 3780.70 VAC decreasing at primary (Vp)<br>= (3780.70/4160) * 100% = 90.88% 4160VAC decreasing at primary |
| Lower Allowable Value (setpoint) | = 107.35 VAC (89.46% 120VAC) decreasing at secondary (Vs, Vr)<br>= 107.35 VAC * 35 = 3757.25 VAC decreasing at primary (Vp)<br>= (3757.25/4160) * 100% = 90.32% 4160VAC decreasing at primary |

This allows for a minimum margin of 0.22 VAC (0.20% of the lower calibration limit of 107.90 VAC).

**Table 8 – Bus 2G Calculation of Limiting Values (Undervoltage Function)**

| | | At Reset Point | | Reset Point at Upper Calibration Limit | | Reset Point at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| Upper Analytical Limit (UAL) ** (Vr) | | 110.64 | 92.20 | 110.64 | 92.20 | 110.64 | 92.20 |
| Upper Margin (UM) | | 0.12 | 0.10 | 0.00 | 0.00 | 0.24 | 0.20 |
| Adjusted UAL (UAL-UM) | | 110.52 | 92.10 | 110.64 | 92.20 | 110.40 | 92.00 |
| Upper Allowable Value (UAV) = UCLL + URD | | | | | | 109.86 | 91.55 |
| URD | 0.73 | | | | | 0.80 | 0.67 |
| UCSA | $[1521/\text{SETTING}^2 + 6.0/\text{SETTING} + 1.3054]^{1/2}$ | 1.34 | 1.12 | 1.34 | 1.12 | 1.34 | 1.12 |
| UCLH (Upper Calibration Limit - High) TS RSP = UNTSP + RCSA | | | | **109.30*** | 91.08 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Upper Nominal Reset Point (UNTSP) *pickup* | | **109.18*** | 90.98 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| UCLL (Upper Calibration Limit – Low) = UNTSP – RCSA | | | | | | **109.06*** | 90.88 |

| | | At Setpoint (Proposed Relay Setting) | | Setpoint at Upper Calibration Limit | | Setpoint at Lower Calibration Limit | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **% Setting** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** | **Engineering Units (VAC)** | **%120VAC** |
| LCLH (Lower Calibration Limit - High) = LNTSP + RCSA | | | | **108.75*** | 90.63 | | |
| RCSA | 12.0/SETTING | | | 0.12 | 0.10 | | |
| Lower Nominal Trip Setpoint (LNTSP) *dropout* | | **108.63*** | 90.53 | | | | |
| RCSA | 12.0/SETTING | | | | | 0.12 | 0.10 |
| LCLL (Lower Calibration Limit – Low) TS SP = LNTSP – RCSA | | | | | | **108.51*** | 90.43 |
| LCSA | $[1521/\text{SETTING}^2 + 6.0/\text{SETTING} + 1.3054]^{1/2}$ | 1.33 | 1.11 | 1.33 | 1.11 | 1.33 | 1.11 |
| LRD | 0.73 | 0.80 | 0.67 | 0.80 | 0.67 | | |
| Lower Allowable Value (LAV) = setting value - LRD | | | | 107.95 | 89.96 | | |
| Adjusted LAL (LAL + LM) | | 107.30 | 89.42 | 107.42 | 89.52 | 107.18 | 89.32 |
| Lower Margin (LM) | | 0.34 | 0.28 | 0.46 | 0.38 | 0.22 | 0.18 |
| Lower Analytical Limit (LAL) (Vs) | | 106.96 | 89.13 | 106.96 | 89.13 | 106.96 | 89.13 |

* Indicates setting value used to calculate AV, RCSA and CSA for each section outlined in the Table

** Adjusted for voltage drop of 0.12V at secondary (Assumption 8)

**Bus 2G Undervoltage Function:**

Upper Allowable Value (reset point) = 109.86 VAC (91.55% 120VAC) increasing at relay (Vr)
= 109.86 VAC + 0.12) * 35 = 3849.30 VAC increasing at primary (Assumption 8) (Vp)
= (3849.30/4160) * 100% = 92.53% 4160VAC increasing at primary

Reset point = 109.18 VAC (90.98% 120VAC) increasing at relay (Vr)
= 109.18 VAC + 0.12) * 35 = 3825.50 VAC increasing at primary (Assumption 8) (Vp)
= (3825.50/4160) * 100% = 91.96% 4160VAC increasing at primary

Setpoint = 108.63 VAC (90.53% 120VAC) decreasing at secondary (Vs, Vr)
= 108.63 VAC * 35 = 3802.05 VAC decreasing at primary (Vp)
= (3802.05/4160) * 100% = 91.40% 4160VAC decreasing at primary

Lower Allowable Value (setpoint) = 107.95 VAC (89.96% 120VAC) decreasing at secondary (Vs, Vr)
= 107.95 VAC * 35 = 3778.25 VAC decreasing at primary (Vp)
= (3778.25/4160) * 100% = 90.82% 4160VAC decreasing at primary

This allows for a minimum margin of 0.22 VAC (0.20% of the lower calibration limit of 108.51 VAC)

Design Inputs (DI):

(1) IB 7.4.1.7-7, ABB Instructions Single Phase Voltage Relays (Attachment B)

(2) NMP-ES-033-004, Version 6.0, Setpoint Control Program Farley Setpoint Uncertainty Methodology and Scaling Instructions

(3) Calculation SE-92-2204-2-PE, Version 3.0, Analysis of P.T. Accuracy for 4kV Buses 1F, 1G, 2F and 2G

(4) Calculation SE-SNC529029-001, Version 1.0, Unit 1 Minimum Expected Voltage Study

(5) Calculation E-035.01.C, Version 2.0, Setting of Protective Relays for FNP Unit 1 125VDC Auxiliary Power System

(6) Calculation E-095, Version 13.0, Auxiliary Building Battery Capacity and Voltage Evaluation

(7) Calculation E-098, Version 5.0, Criteria For Circuit Lengths For 125V DC Control Circuits

(8) Calculation SE-SNC529029-002, Version 1.0, Unit 2 Minimum Expected Voltage Study

(9) Edwin I. Hatch Nuclear Plant Unit No 1 & 2 Document H12619, Version 12.0, Architectural – Generator Building Heating & Ventilating General Arrangement & Parts Numbers

(10) EPRI TR-103335, "Guidelines for Instrument Calibration Extension / Reduction – Revision 1"

(11) NUREG-1475, Revision 1, "Applying Statistics"

(12) ANSI N15.15-1974, "Assessment Of The Assumption Of Normality (Employing Individual Observed Values)"

(13) Southern Nuclear Plant E. I. Hatch Surveillance Procedure, 57SV-S32-002-1, Version 11.0, "Emergency Buses 1E, 1F, and 1G Undervoltage Relay Instrument FT&C"

(14) Southern Nuclear Plant E. I. Hatch Surveillance Procedure, 57SV-S32-002-2, Version 13.2, "Emergency Buses 2E, 2F, and 2G Undervoltage Relay FT&C"

(15) FNP FSAR Section 3.11.2.2, Equipment Outside Containment, Rev 21, dated 5/08

(16) FNP FSAR Section 9.4.2.1.1, Nonradioactive Area Heating and Ventilating System, Rev 24, dated 10/12

References:

(1) ISA-RP67.04.02-2000, "Recommended Practice, Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation"