CAROLINA POWER & LIGHT COMPANY

NUCLEAR ENGINEERING & LICENSING

DEPARTMENT

ADDENDUM TO LOW VOLTAGE (208/120 VOLT) ELECTRICAL DISTRIBUTION SYSTEM STUDY FOR BRUNSWICK STEAM ELECTRIC PLANT UNITS NO. 1 & 2

TAR NT-124

CAROLINA POWER & LIGHT COMPANY

NUCLEAR ENGINEERING & LICENSING DEPARTMENT

ADDENDUM TO LOW VOLTAGE (208/120 VOLT) ELECTRICAL DISTRIBUTION SYSTEM STUDY FOR BRUNSWICK STEAM ELECTRIC PLANT UNITS 1 AND 2

TAR NT-124

Safety Classification: Nuclear Safety-Related

Seismic Classification: N/A

Rev. No.	Prepared by/ Date	Verified by/ Date	Proj. Eng./ Date	Princ. Eng./ Date	Pages Affected
0	Ha Nguyen 7/30/84	John Kowalchuk 7/30/84	W K Russell 7/30/84	W W Pree Jr 7/30/84	ALL

TABLE OF CONTENTS

List of Effective Pages

1.0 Purpose

This calculation serves as an addendum to the Low Voltage (208/120 volt) Electrical Distribution System Study, Revision 1, July 27, 1984, conducted by Duke Power Company (Reference 6.1). The purpose of this addendum is to perform a more detailed analysis of the three (3) 120 volt safety-related circuits which were identified as having a potential undervoltage problem under a postulated loss of coolant accident (LOCA).

2.0 Summary of Results

The Low Voltage Electrical Distribution Study (Reference 6.1) identified three (3) safety-related circuits which did not meet the voltage regulation performance criteria under a postulated degraded voltage condition following a LOCA ("LOCA-Run"). The load data used in the calculation (References 6.2 and 6.3) included some generic conservative assumptions to provide the "worst case" results for all circuits analyzed. Each circuit was represented as one single lumped load with impedance of the longest feeder length in the circuit. A detailed analysis of each of the three (3) circuits (see Appendix A) revealed that all voltage criteria are met when the above referenced conservatisms are removed. A summary of the results is shown in Table 1, Page 4.

3.0 Method of Calculation

A detailed voltage calculation was performed for each of the three (3) circuits. In each circuit, a voltage calculation was done for the component that has the lowest terminal voltage (i.e., the largest load at the far end of the circuit).

4.0 Discussion of Results

The three (3) circuits identified as having potential undervoltage problems during a LOCA-Run condition are:

1. Circuit 12, Panel 2D
2. Circuit 18, Panel 1AB-TB
3. Circuit 16, Panel 2AB-TB

An explanation of each circuit analyzed follows:

4.1 Circuit 12, Panel 2D

This circuit from Reference 6.1 was assumed as a single lumped load with feeder size, length, load, and terminal voltage as follows:

Feeder Size:	#12
Length:	1961 ft.
Load:	240 VA @ 0.5 PF (LAG)
Load Terminal Voltage:	0.8929 p.u.

This circuit actually consists of several components which are described in Figure 3 on Page A4. The detailed voltage calculation for this circuit based on the actual circuit arrangement described on Pages A4, A5, and A6 revealed that the component with the lowest voltage is 20/c with a terminal voltage of 0.9376 p.u. Since this voltage is above the minimum required voltage of 0.90 p.u., no modifications are required.

4.2 Circuit 18, Panel 1AB-TB

This circuit from Reference 6.1 was assumed as a single lumped load with feeder size, length, load, and terminal voltage as follows:

Feeder Size:	#12
Length:	908 ft.
Load:	882 VA @ 0.5 PF (LAG)
Load Terminal Voltage:	0.8398 p.u.

This circuit actually consists of several loads which are described in Figure 5 on Page A7. The detailed voltage calculation for this circuit based on the actual circuit arrangement described in Pages A7, A8, and A9 revealed that the component with the lowest voltage is Contactor #4 with a terminal voltage of 0.9450 p.u. Since this voltage is above the minimum required voltage of 0.90 p.u., no modifications are required.

4.3 Circuit 16 of Panel 2AB-TB

This circuit from Reference 6.1 was assumed as a single lumped load with feeder size, length, load, and terminal voltage as follows:

Feeder size:	#12
Length:	648 ft.
Load	882 VA @ 0.5 PF (LAG)
Load Terminal Voltage:	0.8732 p.u.

Circuit 16 of Panel 2AB-TB actually consists of several loads which are described in Figure 7 on Page A10. The detailed calculation based on the actual arrangement as described on Pages A10, A11, and A12 revealed that the component with the lowest voltage is Contactor #3 with a terminal voltage of 0.9460 p.u. Since this voltage is above the minimum required voltage of 0.90 p.u., no modifications are required.

5.0 Conclusions:

The detailed analysis of each of the three (3) circuits identified as having a potential undervoltage problem showed that the 208/120 VAC safety system maintains adequate voltage during LOCA-Run and no modifications are required.

6.0 References

6.1 Carolina Power & Light Company, Brunswick Steam Electric Plant Units 1 & 2 Low Voltage (208/120 volt) Electrical Distribution System Study, Revision 1, July 27, 1984.

6.2 UE&C Calculation 7453-127-3-ED00-01, Rev. 1. Date: July 24, 1984.

6.3 UE&C Calculation 7453-227-3-ED00-01, Rev. 1. Date: July 24, 1984.

6.4 Drawing LL-9046-G.208, Rev. 2.

6.5 Drawing LL-LL-9046-G.209, Rev. 6.

6.6 Drawing LL-90046-E.15, Rev. 0.

6.7 Drawing LL-90046-E.16, Rev. 0.

6.8 Drawing 9527-F-9052, Rev. 0.

6.9 Drawing 9527-F-90052, Rev. 1.

TABLE 1

LOAD TERMINAL VOLTAGE

PANEL	CIRCUIT NO.	PANEL VOLTAGE /VP/ @ 115 VAC (B.U.)	*LOAD TERMINAL VOLTAGE /VL/ @ 115 VAC (P.U.)	**LOAD TERMINAL VOLTAGE /VL/ @ 115 VAC (P.U.)
2D	12	0.9676	0.8929	0.9376
1AB-TB	18	0.9658	0.8398	0.9450
2AB-TB	16	0.9634	0.8732	0.9460

*Based on Reference 6.1 calculation

**Based on detailed calculation

7.0 APPENDIX A

SUPPLEMENTAL CALCULATIONS TO 208/120 VOLT STUDY

Computed by: Ha Nguyen	Date: 7/13/84	CAROLINA POWER & LIGHT COMPANY	Calculation ID: NT124-E-74-F	
Checked by: P.S. Reddy	Date: 7/18/84	NUCLEAR PLANT ENGINEERING DEPARTMENT	Pg. A2 of A12	Rev. 0
TAR No.: NT-124		CALCULATION SHEET	File: BNT-124-AN-5543	
Project Title: BSEP- Elec. DIST. SYSTEM STUDY				
Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120VOLT STUDY				
Status: Prelim. ☐ Final ☒ Void ☐				

Each single phase load circuit can be represented as shown in figure below:

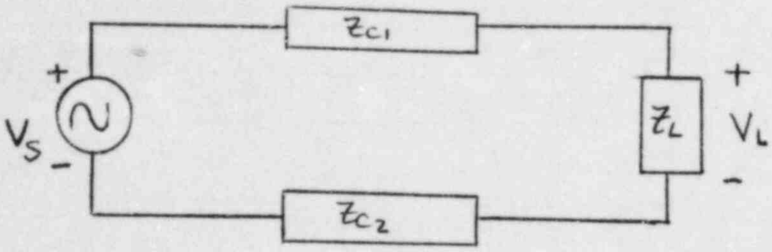


FIGURE 1

V_S = Source voltage

V_L = load Voltage

Z_{C1} = Hot side Feeder Impedance = $R_{C1} + jX_{C1}$

Z_{C2} = Neutral Feeder Impedance = $R_{C2} + jX_{C2}$

The following formulae are used for the voltage calculation.

$$\bar{Z}_L = \frac{V_{RAT}}{\bar{S}_L} = R_L + j X_L \qquad (A.1)$$

All single phase loads in this calculation have a rated voltage (V_{RAT}) of 115 Volts, therefore, the formula (A.1) can be represented as

$$\bar{Z}_L = \frac{115^2}{S_L} = R_L + j X_L \qquad (A.2)$$

where $\bar{S}_L$ = load in VA @ some power factor.

Computed by: Ha Nguyen Date: 7/13/84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124- E-74-F	
Checked by: P.S. Reddy Date: 9/18/84		Pg. A3 of A12	Rev. 0
TAR No.: NT-124		File: BNT-124-AN-5543	
Project Title: BSEP- Elec. DIST. SYST. STUDY			
Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120 VOLT STUDY			
Status: Prelim. ☐ Final ☒ Void ☐			

$$\bar{V}_L = \bar{V}_s \frac{\bar{Z}_L}{Z_{C_1} + Z_{C_2} + Z_L} \qquad (A.3)$$

$$V_L = V_s \times \frac{Z_L}{\left| Z_{C_1} + Z_{C_2} + Z_L \right|}$$

$$V_L = V_s \times \frac{Z_L}{\sqrt{(R_{C_1} + R_{C_2} + R_L)^2 + (X_{C_1} + X_{C_2} + X_L)^2}} \qquad (A.4)$$

Computed by: Ha Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY	Calculation ID: NT124-E-74-F	
Checked by: P.S Reddy	Date: 7/18/84	NUCLEAR PLANT ENGINEERING DEPARTMENT	Pg. A4 of A12	Rev. 0
TAR No.: NT-124		CALCULATION SHEET	File: BNT-124-AN-5543	
Project Title: BSEP - Elec. Dist. Syst. Study				
Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120VOLT STUDY				
Status: Prelim. ☐ Final ☒ Void ☐				

CIRCUIT 12 OF PANEL 2D

As per Reference 6.1 , this circuit can be represented as the following:

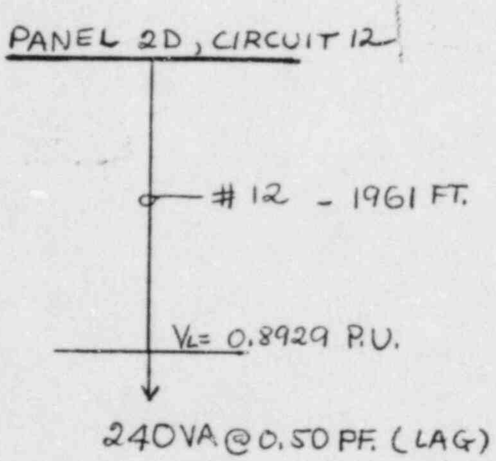
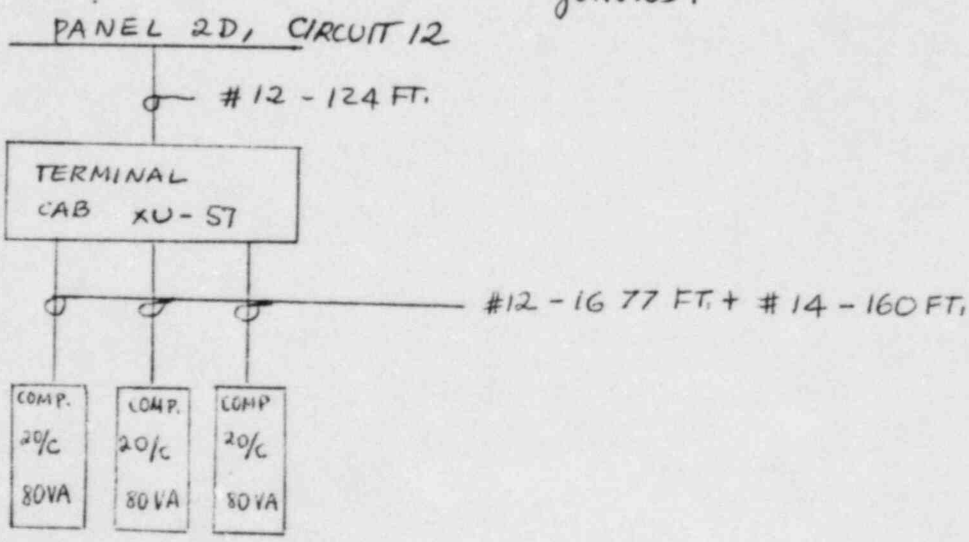


FIGURE 2.

The actual arrangement of circuit 12 of Panel 2D can be represented as follows:



NOTE: 1. 55VA SMALL COMPONENTS NOT SHOWN.

2. ALL LOADS HAVE PF. OF 0.50 (LAG)

FIGURE 3

Computed by: Ha Nguyen	Date: 6/25/84	CAROLINA POWER & LIGHT COMPANY	Calculation ID: NT124-E-74-F	
Checked by: P.S. Reddy	Date: 7/18/84	NUCLEAR PLANT ENGINEERING DEPARTMENT	Pg. A5 of A12	Rev. 0
TAR No.: NT-124		CALCULATION SHEET	File: BNT-124-AN-5543	

Project Title: BSEP - Elec. Dist. syst. Study

Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120VOLT STUDY

Status: Prelim. ☐ Final ☒ Void ☐

VOLTAGE AT TERMINAL CAB XU-57 (V_T)

FEEDER : # 12 - 124 FT.

LOAD: 295VA @ 0.5 PF. (LAG)

$Z_{C1}@75°C = (0.19720 + j\,0.00456) \times 1.24 = 0.24450 + j\,0.00565$

$Z_{C1}@90°C = 0.25624 + j\,0.00565$

$Z_{C2}@90°C = Z_{C1}@90°C$.

From formula A.2

$$\bar{Z}_L = \frac{V_{RAT}}{\bar{S}_L} = \frac{115^2}{295\angle 60°} = 44.8305\angle 60° = 22.4153 + j\,38.8244$$

From formula A.4

$$V_L = V_S \frac{Z_L}{\sqrt{(R_{C1}+R_{C2}+R_L)^2 + (X_{C1}+X_{C2}+X_L)^2}}$$

$$V_T = V_L = 0.9676 \times \frac{44.8305}{\sqrt{(0.25624+0.25624+22.4153)^2 + (0.00565+0.00565+38.8244)^2}}$$

$= 0.9618$ p.u.

Computed by: Ha Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124 - E - 74 - F	
Checked by: P.S. Reaty	Date: 7/18/84		Pg. A6 of A12	Rev. 0
TAR No.: NT - 124			File: BNT-124-AN-S543	
Project Title: BSEP - Elec. DIST. SYST. STUDY				
Calculation Title: SUPPEMENTAL CALCULATIONS TO 208/120VOLT STUDY				
Status: Prelim. ☐ Final ☒ Void ☐				

VOLTAGE AT COMPONENT "20/C" TERMINAL (V_L).

FEEDER : #12-1677 FT + #14-160 FT.

LOAD : 80VA @ 0.5PF. (LAG). , $V_S = 0.9618$ p.u.

Z_{C1} @ 75°C = $(0.19720 + j0.004560) \times 16.77 + (0.31350 + j0.00468) \times 1.60 = 3.8086 + j0.0839$

Z_{C1} @ 90°C = $3.9914 + j0.0839 = Z_{C2}$ @ 90°C.

From formula A.2

$$\bar{Z}_L = \frac{V_L}{\bar{S}_L} = \frac{115^2}{80 \angle -60°} = 165.313 \angle 60° = 82.6565 + j143.1653$$

From formula A.4

$$V_L = V_S \frac{Z_L}{\sqrt{(R_{C1} + R_{C2} + R_L)^2 + (X_{C1} + X_{C2} + X_L)^2}}$$

$$= 0.9618 \frac{165.313}{\sqrt{(3.9914 + 3.9914 + 82.6565)^2 + (0.0839 + 0.0839 + 143.1653)^2}}$$

$= 0.9618 \times 0.9748$

$V_L = 0.9376$ p.u.

Computed by: Ha Nguyen Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124-E-74-F	
Checked by: P.S. Reddy Date: 7/18/84		Pg. A7 of A12	Rev. 0
TAR No.: NT-124		File: BNT-124-AN-5543	
Project Title: BSEP- Elec. DIST. SYST. STUDY			
Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120VOLT STUDY			
Status: Prelim. ☐ Final ☒ Void ☐			

CIRCUIT 18 OF PANEL 1AB-TB

As per Reference 6.1 Calculation, this circuit is represented as the following.

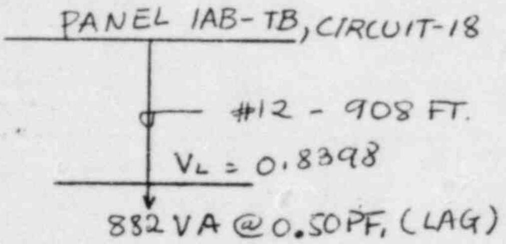


FIGURE 4

The actual circuit arrangement of Circuit 18 of Panel 1AB-TB is the following.

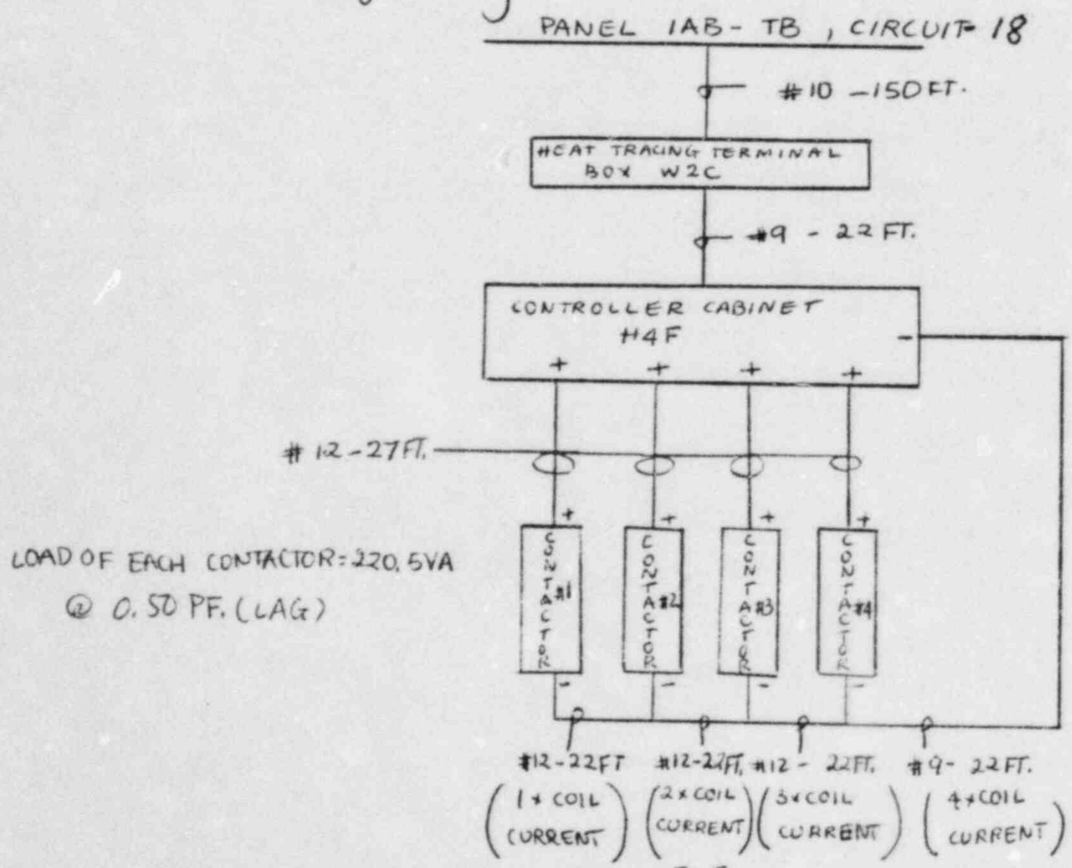


FIGURE 5

Computed by: Ha Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124-E-74-F	
Checked by: P.J. Redding	Date: 9/18/84		Pg. A8 of A12	Rev. 0
TAR No.: NT-124			File: BNT-124-AN-5543	
Project Title: BSEP- Elec. Dist. Syst. Study				
Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120 VOLT STUDY				
Status: Prelim. ☐ Final ☒ Void ☐				

VOLTAGE AT CONTROLLER CABINET H4F (V_C)

FEEDER : #10 - 150 FT. + #9 - 22 FT.*

LOAD : 882VA @ PF. = 0.5 (LAG) , $V_S = 0.9658$ P.U. (from reference 6.1)

$Z_{C_1} @ 75^\circ C = (0.12400 + j0.00448) \times (1.50 + 0.22) = 0.2133 + j0.0077$

$Z_{C_1} @ 90^\circ C = 0.2235 + j0.0077$

$Z_{C_2} @ 90^\circ C = Z_{C_1} @ 90^\circ C$

$Z_{C_2} @ 90^\circ C = 0.2235 + j0.0077$

From formula A.2

$$\bar{Z}_L = \frac{V_{RAT}}{\bar{S}_L} = \frac{115}{882\angle -60^\circ} = 14.9943\angle 60^\circ = 7.4972 + j12.9854$$

From formula A.4

$$V_L = V_S \frac{Z_L}{\sqrt{(R_{C_1} + R_{C_2} + R_L)^2 + (X_{C_1} + X_{C_2} + X_L)^2}}$$

$$= 0.9658 \frac{14.9943}{\sqrt{(0.2235 + 0.2235 + 7.4972)^2 + (0.0077 + 0.0077 + 12.9854)^2}}$$

$V_C = V_L = 0.9505$ P.U.

* NOTE : SINCE #9 WIRE CABLE IMPEDANCE IS NOT AVAILABLE, #10 WIRE CABLE IMPEDANCE IS USED IN CALCULATION TO BE CONSERVATIVE.

Computed by: Ha Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124-E-74-F	
Checked by: P.S. Reddy	Date: 7/17/84		Pg. A9 of A12	Rev. 0
TAR No.: NT-124			File: BNT-124-AN-5543	

Project Title: BSEP- Elec. DIST. SYST. STUDY

Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120 VOLT STUDY

Status: Prelim. ☐ Final ☒ Void ☐

VOLTAGE AT CONTACTOR # 4 TERMINAL (V_L)

POSITIVE FEEDER : #12 - 27FT.

* NEGATIVE FEEDER : {#12 - (3 × 22FT. + 2 × 22FT. + 22FT.)} + {**#9 (4 × 22 FT.)}

SOURCE VOLTAGE : 0.9505 P.U.

LOAD : 220.5VA @ 0.5 PF. (LAG)

Z_{C1} @ 75°C = $(0.19720 + j\,0.00456) \times 0.27 = 0.0532 + j\,0.0012$

Z_{C1} @ 90°C = $(0.0558 + j\,0.0012)$

Z_{C2} @ 75°C = $(0.19720 + j0.00456) \times (4+3+2+1) \times 0.22$

$= 0.4338 + j\,0.1003$

Z_{C2} @ 90°C = $0.4546 \quad j\,0.1003$

From formula A.2

$$\bar{Z}_L = \frac{V_{RAT}^2}{\bar{S}_L} = \frac{115^2}{220.5 \angle -60^\circ} = 59.9773 \angle 60^\circ = 29.9989 + j\,51.9419$$

From formula A.4

$$V_L = V_S \frac{Z_L}{\sqrt{(R_{C1} + R_{C2} + R_L)^2 + (X_{C1} + X_{C2} + X_L)^2}}$$

$$= 0.9505 \times \frac{59.9773}{\sqrt{(0.0558 + 0.4546 + 29.9989)^2 + (0.0012 + 0.1003 + 51.9419)^2}}$$

V_L = 0.9450 P.U.

* NOTE: The lengths are multiplied with appropriate numbers of neutral currents

** NOTE: #9 FEEDER is treated as #12 Feeder for conservative results.

Computed by: Ha Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY	Calculation ID: NT124-E-74-F	
Checked by: P.S. Reddy	Date: 9/11/84	NUCLEAR PLANT ENGINEERING DEPARTMENT	Pg. A10 of A12	Rev. 0
TAR No.: NT-124		CALCULATION SHEET	File: BNT-124-AN-S543	
Project Title: BSEP - Elec. Dist. Syst. study				
Calculation Title: SUPPEMENTAL CALCULATIONS TO 208/120VOLT STUDY				
Status: Prelim. ☐ Final ☒ Void ☐				

CIRCUIT 16 OF PANEL 2AB-TB

As per Reference 6.1 calculation, this circuit is presented as follows.

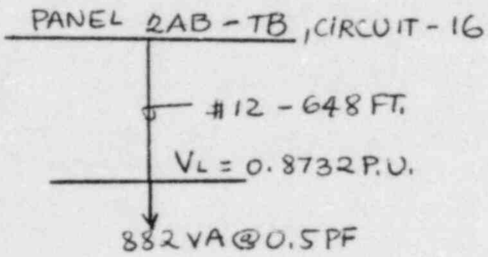


FIGURE 6

The actual circuit arrangement of Circuit 16 of Panel 2AB-TB is the following

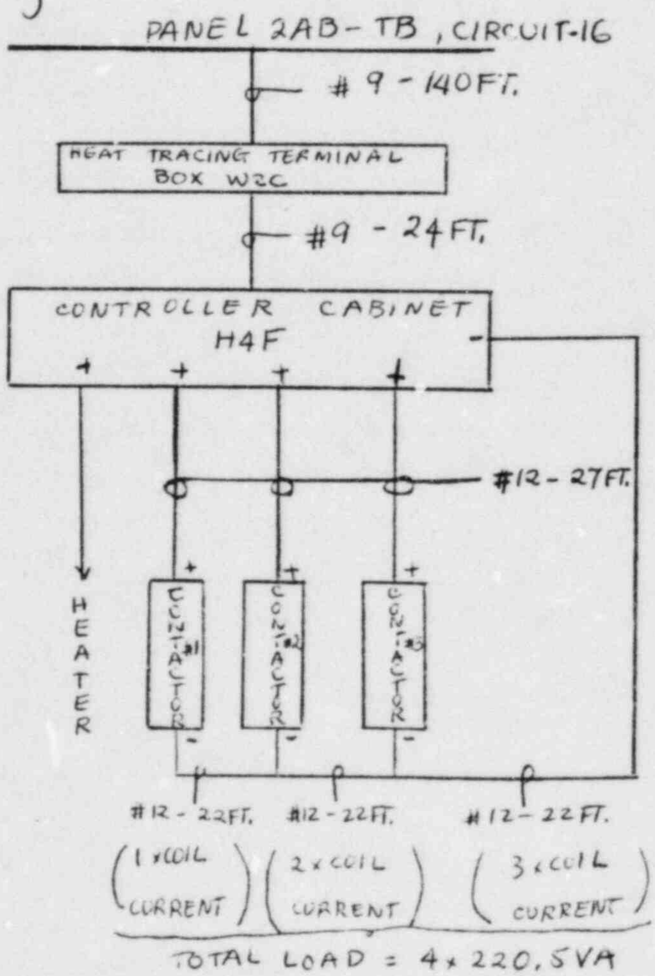


FIGURE 7

Computed by: Hai Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124-E-74-F	
Checked by: P. Sheats	Date: 7/18/84		Pg. A11 of A12	Rev. 0
TAR No.: NT-124			File: BNT-124-AN-S543	

Project Title: BSEP- Elec. Dist. Syst. study

Calculation Title: SUPPEMENTAL CALCULATIONS TO 208/120VOLT STUDY

Status: Prelim. ☐ Final ☒ Void ☐

VOLTAGE AT CONTROLLER CABINET H4F (Vc)

FEEDER: (#9 - 140 FT + #9 - 24 FT.)*

LOAD : 882 VA @ PF = 0.50 (LAG)

V_S : 0.9634 p.u. (from Reference 6.1)

Z_{C1} @ 75°C = $(0.12400 + j0.00448)^* \times 1.64 = 0.2034 + j0.0073$

Z_{C1} @ 90°C = $0.2132 + j0.0073$

Z_{C2} @ 90°C = Z_{C1} @ 90°C

From formula A.2

$$\bar{Z}_L = \frac{V_{RAT}^2}{\bar{S}_L} = \frac{115^2}{882\angle -60^\circ} = 14.9943\angle 60^\circ = 7.4972 + j12.9854$$

From formula A.4

$$V_L = V_S \times \frac{Z_L}{\sqrt{(R_{C1} + R_{C2} + R_L)^2 + (X_{C1} + X_{C2} + X_L)^2}}$$

$$= 0.9634 \frac{14.9943}{\sqrt{(0.2132 + 0.2132 + 7.4972)^2 + (0.0073 + 0.0073 + 12.9854)^2}}$$

$V_C = V_L = 0.9488$ P.U.

* NOTE: SINCE #9 WIRE CABLE IMPEDANCE IS NOT AVAILABLE, #10 WIRE CABLE IMPEDANCE IS USED IN CALCULATION TO BE CONSERVATIVE.

Computed by: Ha Nguyen	Date: 7-13-84	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: NT124-E-74-F	
Checked by: P S Reddy	Date: 7/18/84		Pg. A12 of A12	Rev. 0
TAR No.: NT-124			File: BNT-124-AN-5543	

Project Title: BSEP- Elec. DIST. SYST. STUDY

Calculation Title: SUPPLEMENTAL CALCULATIONS TO 208/120VOLT STUDY

Status: Prelim. ☐ Final ☒ Void ☐

VOLTAGE AT CONTACTOR #3 TERMINAL (V_L)

POSITIVE FEEDER: #12 - 27FT.

* NEGATIVE FEEDER: #12 - (3x22FT. + 2x 22FT. + 22FT.)

SOURCE VOLTAGE: 0.9488 P.U.

LOAD: 220.5 VA @ 0.50 PF. (LAG)

$Z_{C1}@75°C = (0.19720 + j\,0.00456) \times 0.27 = 0.0532 + j\,0.0012$

$Z_{C1}@90°C = (0.0558 + j\,0.0012)$

$Z_{C2}@75°C = (0.19720 + j\,0.00456) \times (3+2+1)\,0.22 = 0.2603 + j\,0.0062$

$Z_{C2}@90°C = 0.2728 + j\,0.0062$

From formula A.2

$$\bar{Z}_L = \frac{115^2}{\bar{S}_L} = \frac{115^2}{220.5\angle{-60°}} = 59.9773\angle{60°} = 29.9989 + j\,51.9419$$

From formula A.4

$$V_L = V_S \times \frac{Z_L}{\sqrt{(R_{C1}+R_{C2}+R_L)^2 + (X_{C1}+X_{C2}+X_L)^2}}$$

$$= 0.9488 \times \frac{59.9773}{\sqrt{(0.0558+0.2728+29.9989)^2 + (0.0012+0.0062+51.9419)^2}}$$

$V_L = 0.9460$ P.U.

* NOTE: The lengths are multiplied with appropriate number of neutral currents.