NASHVILLE VA PARKING GARAGE - SHORT CIRCUIT AND COORDINATION STUDY

Prepared by

GTP Consulting Engineers

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Checking is only for general conformance with the design concept of the project and general compliance with the information given in the contract documents. Any action shown is subject to the requirements of the plans and specifications. Contractor is responsible for dimensions which shall be confirmed and correlated at the job site, fabrication processes and techniques of construction, coordination of the work, and the satisfactory performance of the work.

✓ NO EXCEPTION TAKEN

_____ MAKE CORRECTIONS NOTED

_____ REVISE AND RESUBMIT

_____ REJECTED, SEE REMARKS

NASHVILLE VA PARKING GARAGE - SHORT CIRCUIT AND COORDINATION STUDY

Updated by

Drew Philippo

January 30, 2012

GTP
Consulting Engineers

This study is a fault-current and coordination study of an existing electrical system design. This study is not an evaluation of the system's design, design methodology, or design intent. The author of this study disclaims any responsibility for the design, safety, or suitability of the electrical system and components. Any distribution-system modifications suggested herein are intended for the use of the owner to aid in their assessment of the distribution system.

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OVERVIEW

Purpose

This report consists of two studies—a fault-current calculation study and an overcurrent-protection coordination study.

The purpose of the fault-current study is to determine the available fault current at each panel and device in the facility's distribution system. This data is then used to calculate the incident fault energy at each point in the system.

The purpose of the overcurrent-protection coordination study is to assess the coordination between upstream and downstream devices in the facility's distribution system. This study provides circuit-breaker settings to maximize coordination between those devices.

Scope

The scope of this report includes the new panelboards in the parking garage.

Description of Sections

The results are divided into four sections, providing the following information:

- The ***System Description*** section contains the one-line drawing used to perform the calculations along with the input data for the system components.
- The ***Fault-Current Results*** section presents the results of the fault-current calculation study. It shows a summary table of the available fault current for all devices within the scope of this project along with an equipment evaluation table for all of the equipment. It also includes the computer program output summary results.
- The ***Time-Current Coordination (TCC) Results*** section provides a summary of the overcurrent-protection coordination study. It includes a table of recommended circuit-breaker settings along with the associated time-current coordination curves.
- The ***Study Methodology*** section, presents a summary of the calculation methodology used to create this report. It also lists any assumptions that were made during the course of the calculations. Backup information provided to perform the study is also included in this section.

Executive Summary

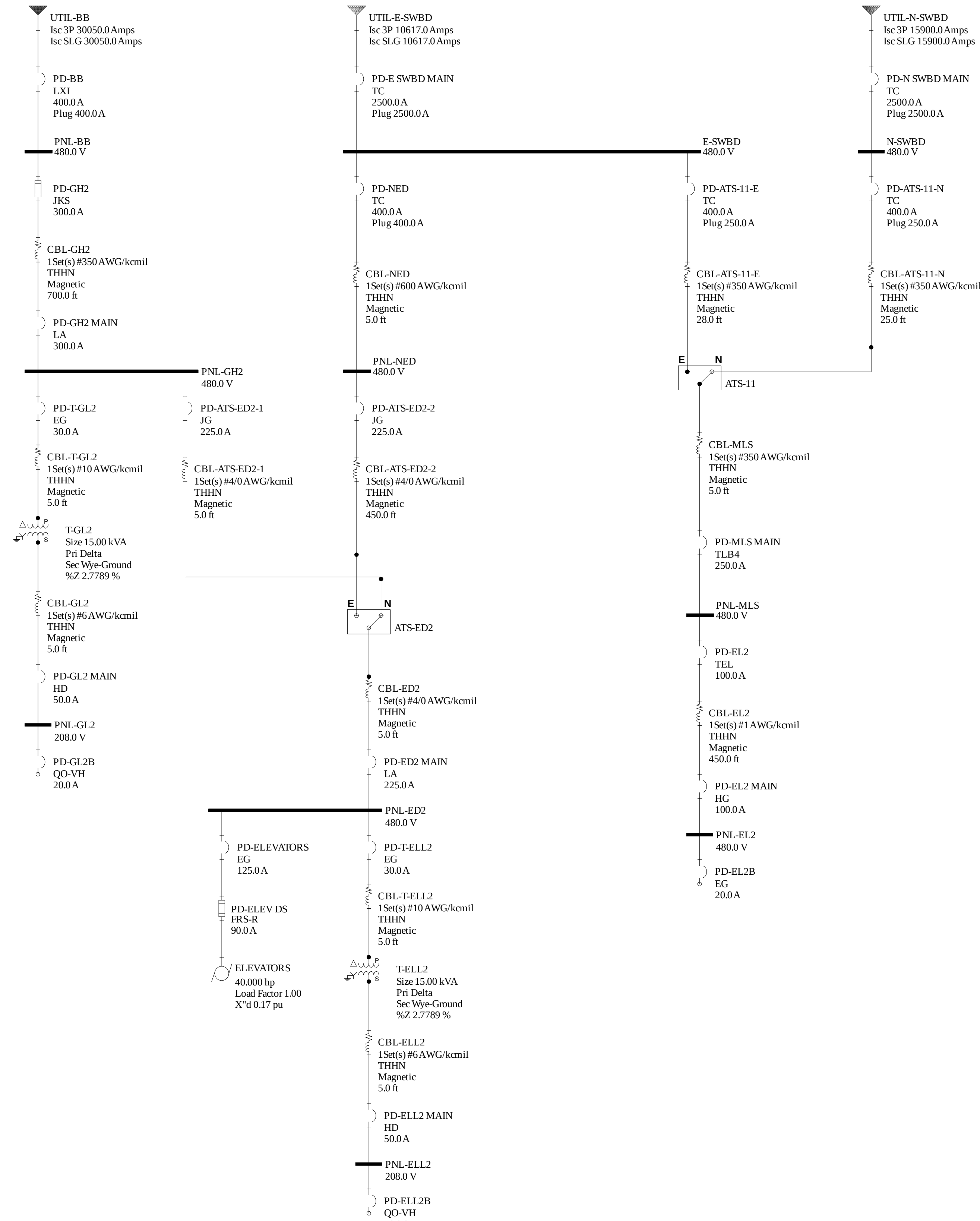
The calculations and the relevant input and output information are included in the sections described above. Overall the study yielded positive results for the various calculations with no problematic issues.

- **Fault Current:** All of the AIC ratings for the equipment are adequate for the available fault at the equipment.
- **Time-Current Coordination:** Overall there is good coordination in the system. Where there is a lack of coordination, it is in the normal bus or between devices in the parking garage and should not be considered a cause for concern.

SYSTEM DESCRIPTION

Summary

The first page in this section contains the one-line drawing used to perform the calculations. Following the one-line drawing is the input data for all of the system components.



Oneline: ~One-Line

January 30, 2012

Project: Nashville VA Parking Garage

DAPPER Fault Analysis Input Report (English)

Utilities

Contribution From Name	Bus Name	In/Out Service	Nominal Voltage		-------- Contribution Data -------- Duty	Units	X/R		PU (100 MVA Base R PU	X PU
UTIL-BB	PNL-BB	In	480	3P:	30,050	Amps	8.00	Pos:	0.496	3.972
				SLG:	30,050	Amps	8.00	Zero:	0.496	3.972
UTIL-E-SWBD	E-SWBD	In	480	3P:	10,617	Amps	8.00	Pos:	1.405	11.242
				SLG:	10,617	Amps	8.00	Zero:	1.405	11.242
UTIL-N-SWBD	N-SWBD	In	480	3P:	15,900	Amps	8.00	Pos:	0.938	7.506
				SLG:	15,900	Amps	8.00	Zero:	0.938	7.506

Motors

Contribution From Name	# of Motors	Bus Name	In/Out Service	Nominal Voltage	--------- Contribution Data -------- Base kVA	Xd"	X/R	PU (100 MVA Base) R PU	X PU
ELEVATORS	2	PNL-ED2	In	480	40.11	0.1692	10.00	21.092	210.933

Cables

Cable Name	From Bus To Bus	In/Out Service	Qty /Ph	Length Feet	------ Cable Description ------ Size	Cond. Type	Duct Type	Insul	Per Unit (100 MVA Base)	R pu	jX pu
CBL-ATS-11-E	E-SWBD	In	1	28	350	Copper	Magnetic	PVC	Pos:	0.4594	0.5967
									Zero:	1.4474	1.4693
	BUS-0015										

Cable Name	From Bus / To Bus	In/Out Service	Qty /Ph	Length Feet	Size	Cond. Type	Duct Type	Insul		R pu	jX pu
					------ Cable Description ------				Per Unit (100 MVA Base)		
CBL-ATS-11-N	N-SWBD	In	1	25	350	Copper	Magnetic	PVC	Pos:	0.4102	0.5328
									Zero:	1.2923	1.3118
	BUS-0016										
CBL-ATS-ED2-1	PNL-GH2	In	1	5	4/0	Copper	Magnetic	PVC	Pos:	0.1389	0.1079
									Zero:	0.4377	0.2656
	BUS-0012										
CBL-ATS-ED2-2	PNL-NED	In	1	450	4/0	Copper	Magnetic	PVC	Pos:	12.5000	9.7070
									Zero:	39.3945	23.9063
	BUS-0013										
CBL-ED2	BUS-0010	In	1	5	4/0	Copper	Magnetic	PVC	Pos:	0.1389	0.1079
									Zero:	0.4377	0.2656
	PNL-ED2										
CBL-EL2	PNL-MLS	In	1	450	1	Copper	Magnetic	PVC	Pos:	31.2500	11.1328
									Zero:	98.4766	27.4023
	PNL-EL2										
CBL-ELL2	BUS-0005	In	1	5	6	Copper	Magnetic	PVC	Pos:	5.8940	0.7917
									Zero:	18.5743	1.9497
	PNL-ELL2										
CBL-GH2	PNL-BB	In	1	700	350	Copper	Magnetic	PVC	Pos:	11.4844	14.9175
									Zero:	36.1849	36.7318
	PNL-GH2										
CBL-GL2	BUS-0004	In	1	5	6	Copper	Magnetic	PVC	Pos:	5.8940	0.7917
									Zero:	18.5743	1.9497
	PNL-GL2										
CBL-MLS	BUS-0017	In	1	5	350	Copper	Magnetic	PVC	Pos:	0.0820	0.1066
									Zero:	0.2585	0.2624
	PNL-MLS										
CBL-NED	E-SWBD	In	1	5	600	Copper	Magnetic	PVC	Pos:	0.0558	0.1005
									Zero:	0.1756	0.2474
	PNL-NED										

Cable Name	From Bus To Bus	In/Out Service	Qty /Ph	Length Feet	------ Cable Description ------ Size	Cond. Type	Duct Type	Insul	Per Unit (100 MVA Base)	R pu	jX pu
CBL-T-ELL2	PNL-ED2	In	1	5	10	Copper	Magnetic	PVC	Pos:	2.5608	0.1853
									Zero:	8.0703	0.4564
	BUS-0009										
CBL-T-GL2	PNL-GH2	In	1	5	10	Copper	Magnetic	PVC	Pos:	2.5608	0.1853
									Zero:	8.0703	0.4564
	BUS-0006										

2-Winding Transformers

Xformer Name	In/Out Service	------------------Primary & Secondary--------------- Bus	Conn.	Volts	FLA	Nominal kVA	Z PU (100 MVA Base)	R pu	jX pu
T-ELL2	In	BUS-0009	D	480	18	15.0	Pos:	140.0000	121.3333
			WG	208	42		Zero:	140.0000	121.3333
		BUS-0005							
T-GL2	In	BUS-0006	D	480	18	15.0	Pos:	140.0000	121.3333
			WG	208	42		Zero:	140.0000	121.3333
		BUS-0004							

FAULT-CURRENT RESULTS

Summary

This section presents the results of the fault-current calculation study. The first page is a summary table of available fault current for all of the switchboards and panelboards. Following the fault-current table are the computer program output results.

All of the new equipment AIC ratings are adequate for the available fault current at the equipment. The fault current values at the existing panelboards/switchboards were obtained from a previous study performed by GE in 1992 and another performed by Nash, Lipsey, Burch in 2000. Regardless, given the length of the feeders from the main building to the parking garage, the available fault current at the garage will always be low.

Nashville VA Parking Garage - Fault-Current Study Results						
Switchboard/Panel	RMS Sym. 3-Phase Current (Amps)	X/R	RMS Sym. Single Line to Ground Current (Amps)	Bus Voltage	Equipment AIC Rating (Amps)	Notes
PNL-ED2	5,810	1.72	3,734	480	22,000	
PNL-EL2	3,170	0.59	1,978	480	22,000	
PNL-ELL2	1,310	0.88	1,334	208	22,000	
PNL-GH2	5,889	1.74	3,794	480	22,000	
PNL-GL2	1,312	0.88	1,335	208	22,000	
PNL-NED	10,518	7.76	10,469	480	22,000	

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SKM POWER*TOOLS FOR WINDOWS
SHORT CIRCUIT ANALYSIS REPORT

ALL PU VALUES ARE EXPRESSED ON A 100 MVA BASE

SWING GENERATORS

SOURCE NAME	VOLTAGE	ANGLE
UTIL-E-SWBD	1.00	0.00
UTIL-N-SWBD	1.00	0.00
UTIL-BB	1.00	0.00

************* P R E - F A U L T   V O L T A G E   P R O F I L E **************

BUS# NAME	BASE VOLTS	PU VOLTS	ANGLE (D)
BUS-0004	208.00	1.0000	-30.
BUS-0005	208.00	1.0000	-30.
BUS-0006	480.00	1.0000	0.
BUS-0009	480.00	1.0000	0.
BUS-0010	480.00	1.0000	0.
BUS-0012	480.00	1.0000	0.
BUS-0013	480.00	1.0000	0.
BUS-0015	480.00	1.0000	0.
BUS-0016	480.00	1.0000	0.
BUS-0017	480.00	1.0000	0.
E-SWBD	480.00	1.0000	0.
N-SWBD	480.00	1.0000	0.
PNL-BB	480.00	1.0000	0.
PNL-ED2	480.00	1.0000	0.
PNL-EL2	480.00	1.0000	0.
PNL-ELL2	208.00	1.0000	-30.
PNL-GH2	480.00	1.0000	0.
PNL-GL2	208.00	1.0000	-30.
PNL-MLS	480.00	1.0000	0.
PNL-NED	480.00	1.0000	0.

```
***************** F A U L T   A N A L Y S I S   R E P O R T ****************

                FAULT TYPE: 3PH
                MODEL INDUCTION MOTOR CONTRIBUTION: YES
                MODEL TRANSFORMER TAPS: YES
                MODEL TRANSFORMER PHASE SHIFT: YES
==============================================================================
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```
  E-SWBD         VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  10617.0 /  -83. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    1.405 +j  11.242 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     8.000

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    14680.2     11066.3     10712.0     10621.1     10617.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 10617.0 / -82.9    10617.0 / 157.1     10617.0 /  37.1

  E-SWBD         ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    PNL-NED           480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    BUS-0015          480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    E-SWBD         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                              FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                             BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 UTIL-E-SWBD    E-SWBD                            480.  10617.0/ -83.  10617.0/ 157.  10617.0/
37.
 E-SWBD         PNL-NED        CBL-NED           480.      0.0/   0.      0.0/   0.      0.0/
0.
 E-SWBD         BUS-0015       CBL-ATS-11-E      480.      0.0/   0.      0.0/   0.      0.0/
0.

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```
  N-SWBD         VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  15900.0 /  -83. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    0.938 +j   7.506 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     8.000

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    21985.0     16572.9     16042.2     15906.2     15900.1

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 15900.0 / -82.9    15900.0 / 157.1     15900.0 /  37.1

  N-SWBD         ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0016          480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    N-SWBD         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 UTIL-N-SWBD    N-SWBD                            480.  15900.0/ -83.  15900.0/ 157.  15900.0/
37.
 N-SWBD         BUS-0016       CBL-ATS-11-N     480.      0.0/   0.      0.0/   0.      0.0/
0.

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```

```
 PNL-BB         VOLTAGE BASE LL:                480.0 (VOLTS)
                INI. SYM. RMS FAULT CURRENT:  30576.4 /  -83. ( AMPS/DEG )
                THEVENIN EQUIVALENT IMPEDANCE:    0.489 +j   3.903 (PU)
                THEVENIN IMPEDANCE X/R RATIO:     7.978

                 ASYM    RMS   INTERRUPTING AMPS
                1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                   42256.1     31859.3     30846.3     30588.0     30576.5

                INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                30576.4 / -82.9    30576.4 / 157.1     30576.4 /  37.1

 PNL-BB         ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                    FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                          ---PHASE A---     ---PHASE B---     ---PHASE C---
   PNL-GH2         480.0  0.0824 / -29.  0.0824 /-149.  0.0824 /  91.
   PNL-BB         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                             FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                            BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 UTIL-BB        PNL-BB                             480.  30050.0/ -83.  30050.0/ 157.  30050.0/
37.
 PNL-BB         PNL-GH2        CBL-GH2           480.    526.5/  98.    526.5/ -22.    526.5/-
142.

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  PNL-ED2        VOLTAGE BASE LL:                480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   5810.2 /  -60. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:   10.397 +j  17.902 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     1.722

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     5959.4      5810.2      5810.2      5810.2      5810.2

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  5810.2 / -59.9     5810.2 /-179.9      5810.2 /  60.1

  PNL-ED2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0009          480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    BUS-0010          480.0  0.0077 / -19.  0.0077 /-139.  0.0077 / 101.
    PNL-ED2        ================ INI.   RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 ELEVATORS      PNL-ED2                            480.    567.4/ -84.    567.4/ 156.    567.4/
36.
 PNL-ED2        BUS-0009       CBL-T-ELL2       480.      0.0/   0.       0.0/   0.       0.0/
0.
 BUS-0010       PNL-ED2        CBL-ED2           480.   5298.8/ -57.   5298.8/-177.   5298.8/
63.

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```
  PNL-EL2        VOLTAGE BASE LL:                480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   3170.0 /  -31. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:   32.681 +j  19.279 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     0.590

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     3170.1      3170.0      3170.0      3170.0      3170.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  3170.0 / -30.5     3170.0 /-150.5      3170.0 /  89.5

  PNL-EL2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    PNL-MLS           480.0  0.8743 / -11.  0.8743 /-131.  0.8743 / 109.
    PNL-EL2        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 PNL-MLS         PNL-EL2        CBL-EL2           480.   3170.0/ -31.   3170.0/-151.   3170.0/
89.

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  PNL-ELL2       VOLTAGE BASE LL:                 208.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   1310.0 /  -71. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:  158.852 +j 140.212 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     0.883

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     1311.1      1310.0      1310.0      1310.0      1310.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  1310.0 / -71.4     1310.0 / 168.6      1310.0 /  48.6

  PNL-ELL2       ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0005          208.0  0.0281 / -64.  0.0281 / 176.  0.0281 /  56.
    PNL-ELL2       ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 BUS-0005        PNL-ELL2       CBL-ELL2         208.   1310.0/ -71.   1310.0/ 169.   1310.0/
49.

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```
  PNL-GH2        VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   5889.5 /  -60. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:   10.185 +j  17.702 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     1.738

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     6045.9      5889.5      5889.5      5889.5      5889.5

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  5889.5 / -60.1     5889.5 / 179.9      5889.5 /  59.9

  PNL-GH2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0006          480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    PNL-BB            480.0  0.8416 /  -5.  0.8416 /-125.  0.8416 / 115.
    BUS-0012          480.0  0.0008 / -46.  0.0008 /-166.  0.0008 /  74.
    PNL-GH2        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 PNL-GH2        BUS-0006       CBL-T-GL2        480.      0.0/   0.      0.0/   0.      0.0/
0.
 PNL-BB         PNL-GH2        CBL-GH2           480.   5377.3/ -58.   5377.3/-178.   5377.3/
62.
 PNL-GH2        BUS-0012       CBL-ATS-ED2-1    480.    566.8/  96.    566.8/ -24.    566.8/-
144.

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```

```
  PNL-GL2        VOLTAGE BASE LL:                  208.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   1311.8 /  -71. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:  158.640 +j 140.012 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     0.883

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     1312.9      1311.8      1311.8      1311.8      1311.8

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  1311.8 / -71.4     1311.8 / 168.6      1311.8 /  48.6

  PNL-GL2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0004          208.0  0.0281 / -64.  0.0281 / 176.  0.0281 /  56.
    PNL-GL2        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 BUS-0004        PNL-GL2        CBL-GL2           208.   1311.8/ -71.   1311.8/ 169.   1311.8/
49.

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```

```
  PNL-MLS        VOLTAGE BASE LL:                  480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  14543.5 /  -80. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    1.431 +j   8.146 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     5.694

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    18757.6     14718.6     14562.9     14543.8     14543.5

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 14543.5 / -80.0    14543.5 / 160.0     14543.5 /  40.0

  PNL-MLS        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    PNL-EL2           480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    BUS-0017          480.0  0.0163 / -28.  0.0163 /-148.  0.0163 /  92.
    PNL-MLS        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 PNL-MLS        PNL-EL2        CBL-EL2          480.      0.0/   0.      0.0/   0.      0.0/
0.
 BUS-0017       PNL-MLS        CBL-MLS           480.  14543.5/ -80.  14543.5/ 160.  14543.5/
40.

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```
  PNL-NED        VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  10517.9 /   -83. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    1.461 +j  11.342 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     7.763

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    14461.0     10923.2     10599.5     10521.2     10518.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.0000 /    0.0     0.0000 /    0.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 10517.9 / -82.7    10517.9 / 157.3     10517.9 /  37.3

  PNL-NED        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    E-SWBD            480.0  0.0100 / -22.  0.0100 /-142.  0.0100 /  98.
    BUS-0013          480.0  0.0000 /   0.  0.0000 /   0.  0.0000 /   0.
    PNL-NED        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 E-SWBD          PNL-NED         CBL-NED           480.  10517.9/ -83.  10517.9/ 157.  10517.9/
37.
 PNL-NED         BUS-0013        CBL-ATS-ED2-2    480.       0.0/   0.       0.0/   0.       0.0/
0.

 ************************************************************************************************
```

```
***************** F A U L T    A N A L Y S I S    R E P O R T ****************

                FAULT TYPE: SLG
                MODEL INDUCTION MOTOR CONTRIBUTION: YES
                MODEL TRANSFORMER TAPS: YES
                MODEL TRANSFORMER PHASE SHIFT: YES
==============================================================================
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```
  E-SWBD         VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  10617.0 /  -83. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    4.216 +j  33.725 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     8.000
                 SEQUENCE EQUIVALENT IMPEDANCE Z1:   1.405 +j  11.242 (PU)
                                               Z2:   1.405 +j  11.242 (PU)
                                               Z0:   1.405 +j  11.242 (PU)

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    14680.2     11066.3     10712.0     10621.1     10617.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     1.0000 / -120.0     1.0000 /  120.0

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 10617.0 / -82.9        0.0 /   0.0         0.0 /   0.0

  E-SWBD         ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    PNL-NED           480.0  0.0000 /   0.  1.0000 /-120.  1.0000 / 120.
    BUS-0015          480.0  0.0000 /   0.  1.0000 /-120.  1.0000 / 120.
    E-SWBD         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 UTIL-E-SWBD    E-SWBD                             480.  10617.0/ -83.      0.0/ -83.      0.0/ -
83.
 E-SWBD         PNL-NED        CBL-NED           480.      0.0/   0.      0.0/   0.      0.0/
0.
 E-SWBD         BUS-0015       CBL-ATS-11-E      480.      0.0/   0.      0.0/   0.      0.0/
0.

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 N-SWBD         VOLTAGE BASE LL:                 480.0 (VOLTS)
                INI. SYM. RMS FAULT CURRENT:  15900.0 /  -83. ( AMPS/DEG )
                THEVENIN EQUIVALENT IMPEDANCE:    2.815 +j  22.519 (PU)
                THEVENIN IMPEDANCE X/R RATIO:     8.000
                SEQUENCE EQUIVALENT IMPEDANCE Z1:   0.938 +j   7.506 (PU)
                                              Z2:   0.938 +j   7.506 (PU)
                                              Z0:   0.938 +j   7.506 (PU)

                 ASYM    RMS   INTERRUPTING AMPS
                1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                   21985.0     16572.9     16042.2     15906.2     15900.1

                INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                0.0000 /    0.0     1.0000 / -120.0     1.0000 /  120.0

                INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                15900.0 / -82.9        0.0 /   0.0         0.0 /   0.0

 N-SWBD         ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                    FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                          ---PHASE A---     ---PHASE B---     ---PHASE C---
   BUS-0016          480.0  0.0000 /   0.  1.0000 /-120.  1.0000 / 120.
   N-SWBD         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                               FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                              BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 UTIL-N-SWBD    N-SWBD                         480.  15900.0/ -83.      0.0/ -83.      0.0/ -
83.
 N-SWBD         BUS-0016       CBL-ATS-11-N     480.       0.0/   0.       0.0/   0.       0.0/
0.

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  PNL-BB         VOLTAGE BASE LL:                  480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  30398.9 /  -83. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    1.475 +j  11.778 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     7.985
                 SEQUENCE EQUIVALENT IMPEDANCE Z1:   0.489 +j   3.903 (PU)
                                               Z2:   0.489 +j   3.903 (PU)
                                               Z0:   0.496 +j   3.972 (PU)

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    42018.2     31678.0     30668.4     30410.5     30399.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     1.0030 / -120.3     1.0028 /  120.3

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 30398.9 / -82.9        0.0 /   0.0         0.0 /   0.0

  PNL-BB         ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    PNL-GH2           480.0  0.0546 / -29.  1.0038 /-122.  1.0265 / 121.
    PNL-BB         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                 FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                                BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 UTIL-BB        PNL-BB                           480.  30050.0/ -83.    174.5/ -82.    174.5/ -
82.
 PNL-BB         PNL-GH2        CBL-GH2           480.    349.0/  98.    174.5/ -82.    174.5/ -
82.

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```
  PNL-ED2        VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   3733.8 /  -53. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:   58.351 +j  77.038 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     1.320
                 SEQUENCE EQUIVALENT IMPEDANCE Z1:  10.397 +j  17.902 (PU)
                                              Z2:  10.397 +j  17.902 (PU)
                                              Z0:  37.557 +j  41.235 (PU)

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     3765.7      3733.8      3733.8      3733.8      3733.8

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     1.1679 / -137.6     1.2787 /  132.4

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  3733.8 / -52.9        0.0 /   0.0         0.0 /   0.0

  PNL-ED2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0009          480.0  0.0000 /   0.  1.1679 /-138.  1.2787 / 132.
    BUS-0010          480.0  0.0086 / -18.  1.1665 /-137.  1.2753 / 132.
    PNL-ED2         ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 ELEVATORS       PNL-ED2                         480.    243.1/ -77.    121.5/ 103.    121.5/
103.
 PNL-ED2         BUS-0009       CBL-T-ELL2       480.      0.0/   0.      0.0/   0.      0.0/
0.
 BUS-0010        PNL-ED2        CBL-ED2          480.   3513.9/ -51.    121.5/ -77.    121.5/ -
77.

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 PNL-EL2        VOLTAGE BASE LL:                 480.0 (VOLTS)
                INI. SYM. RMS FAULT CURRENT:   1977.5 /  -24. ( AMPS/DEG )
                THEVENIN EQUIVALENT IMPEDANCE:  166.327 +j  75.040 (PU)
                THEVENIN IMPEDANCE X/R RATIO:     0.451
                SEQUENCE EQUIVALENT IMPEDANCE Z1:  32.681 +j  19.279 (PU)
                                              Z2:  32.681 +j  19.279 (PU)
                                              Z0: 100.966 +j  36.483 (PU)

                 ASYM    RMS   INTERRUPTING AMPS
                1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    1977.5      1977.5      1977.5      1977.5      1977.5

                INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                0.0000 /    0.0     1.1879 / -137.8     1.2832 /  133.3

                INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                 1977.5 / -24.3        0.0 /   0.0         0.0 /   0.0

 PNL-EL2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                    FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                          ---PHASE A---     ---PHASE B---     ---PHASE C---
   PNL-MLS           480.0  0.9232 /  -7.  1.0057 /-120.  1.0017 / 120.
   PNL-EL2        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                               FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                              BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 PNL-MLS        PNL-EL2        CBL-EL2          480.   1977.5/ -24.      0.0/   0.      0.0/
0.

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  PNL-ELL2       VOLTAGE BASE LL:                 208.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   1333.7 /  -70. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:  476.278 +j 403.707 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     0.848
                 SEQUENCE EQUIVALENT IMPEDANCE Z1: 158.852 +j 140.212 (PU)
                                              Z2: 158.852 +j 140.212 (PU)
                                              Z0: 158.574 +j 123.283 (PU)

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     1334.5      1333.7      1333.7      1333.7      1333.7

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.9734 / -149.7     1.0091 /   88.5

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  1333.7 / -70.3        0.0 /   0.0         0.0 /   0.0

  PNL-ELL2       ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0005          208.0  0.0490 / -64.  0.9755 /-148.  0.9908 /  88.
    PNL-ELL2       ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 BUS-0005        PNL-ELL2       CBL-ELL2         208.   1333.7/ -70.      0.0/   0.       0.0/
0.

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 PNL-GH2        VOLTAGE BASE LL:                  480.0 (VOLTS)
                INI. SYM. RMS FAULT CURRENT:   3793.7 /  -53. ( AMPS/DEG )
                THEVENIN EQUIVALENT IMPEDANCE:   57.052 +j  76.107 (PU)
                THEVENIN IMPEDANCE X/R RATIO:     1.334
                SEQUENCE EQUIVALENT IMPEDANCE Z1:  10.185 +j  17.702 (PU)
                                              Z2:  10.185 +j  17.702 (PU)
                                              Z0:  36.681 +j  40.704 (PU)

                 ASYM    RMS   INTERRUPTING AMPS
                1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    3827.7      3793.7      3793.7      3793.7      3793.7

                INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                0.0000 /    0.0     1.1670 / -137.5     1.2773 /  132.4

                INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                        AT TIME =     0.5 CYCLES
                ---PHASE A---       ---PHASE B---       ---PHASE C---
                 3793.7 / -53.1        0.0 /   0.0         0.0 /   0.0

 PNL-GH2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                    FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                          ---PHASE A---     ---PHASE B---     ---PHASE C---
   BUS-0006          480.0  0.0000 /   0.  1.1670 /-138.  1.2773 / 132.
   PNL-BB            480.0  0.9006 /  -4.  1.0024 /-120.  1.0017 / 120.
   BUS-0012          480.0  0.0004 / -39.  1.1670 /-138.  1.2775 / 132.
   PNL-GH2        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                           FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                          BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 PNL-GH2        BUS-0006       CBL-T-GL2        480.      0.0/   0.      0.0/   0.      0.0/
0.
 PNL-BB         PNL-GH2        CBL-GH2          480.   3573.0/ -52.    121.7/ -77.    121.7/ -
77.
 PNL-GH2        BUS-0012       CBL-ATS-ED2-1    480.    243.4/ 103.    121.7/ -77.    121.7/ -
77.

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  PNL-GL2        VOLTAGE BASE LL:                 208.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:   1335.0 /  -70. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:  475.855 +j 403.307 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     0.848
                 SEQUENCE EQUIVALENT IMPEDANCE Z1: 158.640 +j 140.012 (PU)
                                              Z2: 158.640 +j 140.012 (PU)
                                              Z0: 158.574 +j 123.283 (PU)

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                     1335.8      1335.0      1335.0      1335.0      1335.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.9736 / -149.7     1.0093 /   88.6

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                  1335.0 / -70.3        0.0 /   0.0         0.0 /   0.0

  PNL-GL2        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    BUS-0004          208.0  0.0490 / -64.  0.9758 /-149.  0.9910 /  88.
    PNL-GL2        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 BUS-0004       PNL-GL2        CBL-GL2          208.   1335.0/ -70.      0.0/   0.      0.0/
0.

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  PNL-MLS        VOLTAGE BASE LL:                 480.0 (VOLTS)
                 INI. SYM. RMS FAULT CURRENT:  13916.0 /  -78. ( AMPS/DEG )
                 THEVENIN EQUIVALENT IMPEDANCE:    5.350 +j  25.372 (PU)
                 THEVENIN IMPEDANCE X/R RATIO:     4.742
                 SEQUENCE EQUIVALENT IMPEDANCE Z1:   1.431 +j   8.146 (PU)
                                              Z2:   1.431 +j   8.146 (PU)
                                              Z0:   2.489 +j   9.081 (PU)

                  ASYM    RMS   INTERRUPTING AMPS
                 1/2 CYCLES    2 CYCLES    3 CYCLES    5 CYCLES    8 CYCLES
                    17222.5     13985.3     13920.9     13916.0     13916.0

                 INI. SYM. RMS FAULTED BUS VOLTAGES ( PU / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 0.0000 /    0.0     0.9952 / -123.1     1.0502 /  121.2

                 INI.    RMS   FAULTED CURRENT ( AMPS / DEG )
                         AT TIME =     0.5 CYCLES
                 ---PHASE A---       ---PHASE B---       ---PHASE C---
                 13916.0 / -78.1        0.0 /   0.0         0.0 /   0.0

  PNL-MLS        ==== INI. SYM. RMS SYSTEM BUS VOLTAGES ( PU / DEG ) =======
                     FIRST BUS FROM FAULT    AT TIME =     0.5 CYCLES
                           ---PHASE A---     ---PHASE B---     ---PHASE C---
    PNL-EL2           480.0  0.0000 /   0.  0.9952 /-123.  1.0502 / 121.
    BUS-0017          480.0  0.0245 / -30.  0.9958 /-123.  1.0418 / 121.
    PNL-MLS        ================ INI.    RMS   SYSTEM BRANCH FLOWS ( AMPS ) ================
                                FIRST BRANCH FROM FAULT AT TIME =     0.5 CYCLES
                               BRANCH NAME   VBASE LL  -PHASE A-     -PHASE B-     -PHASE C-
 PNL-MLS        PNL-EL2        CBL-EL2          480.      0.0/   0.      0.0/   0.      0.0/
0.
 BUS-0017       PNL-MLS        CBL-MLS          480.  13916.0/ -78.      0.0/ -78.      0.0/ -
78.

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TIME-CURRENT COORDINATION

Protective-Device Settings

The tables on the following pages list the recommended protective-device settings for all devices with adjustable trip settings. These settings achieve the coordination as shown on the coordination curves below. These settings have been chosen to provide adequate protection under National Electrical Code (NEC) guidelines while maximizing selectivity. The settings for the existing static trip circuit breakers have been provided for information only and reflect the values provided in the previous studies or from information provided by Carter Concrete.

Time-Current Coordination Graphs

The graphs that follow the protective-device settings table show the time-current coordination (TCC) curves for each of the protective devices. Each plot shows the TCC curves along with the associated section of the one-line drawing. It is important to note that the trip curve for each breaker is cut off on the current scale (x-axis) at the maximum available fault current for that device. This is because that device will never operate in the region of the curve that exceeds the maximum available fault. The suffix B is used to indicate the largest branch circuit breaker in the most downstream panelboard in a set of curves.

Each leg of the distribution system for each piece of switchgear has been included in the study. In some cases where the downstream switchboard or panel feeds two loads with breakers, the largest breaker was chosen to be shown as the worst case for coordination. Where parallel feeds exist, the trip curves for only one set of the breakers has been shown for clarity.

It should be noted that in the very short time instantaneous region (less than 0.05 seconds) that the coordination between many of the devices fails as the trip curve tails out.

Overall the coordination between the circuit breakers and fuses within this project is good. The major area where coordination is an issue is within the normal power elevator distribution.

> **01-GL2** – There is a lack of coordination between the panel GL2 branch breaker and main and feeder breaker in the instantaneous trip region. There is an overlap of the trip curves for the transformer feeder and panelboard main breakers but this does not constitute a lack of coordination since both circuit breakers serve the same load. There is an overlap of the trip curve for the panelboard BB feeder breaker and the panel GH2 main breaker in the thermal magnetic trip region, but the fuse feeding panel GH2 provides the required coordination.

02-ELEV-N – There is a lack of coordination between the elevator feeder breaker and the elevator panel feeder breakers in the instantaneous trip region. There is also a lack of coordination between the panel GH2 feeder fuse, the GH2 main breaker and the elevator panel feeder and main breakers. Using a type RK5 time delay fuse in lieu of the J-Class fuse would help. It might also be possible to provide a smaller circuit breaker feeding the elevators, depending on the starting mechanism for the elevator motors.

03-ELL2-N – There is good coordination between the overcurrent protective devices. There is an overlap of the trip curves for the transformer feeder breaker and the panelboard main breaker but this does not constitute a lack of coordination since both circuit breakers serve the same load.

04-ELEV-E – There is a lack of coordination between the elevator feeder breaker and the elevator panel feeder breakers in the instantaneous trip region. Otherwise, there is good coordination between the overcurrent protective devices.

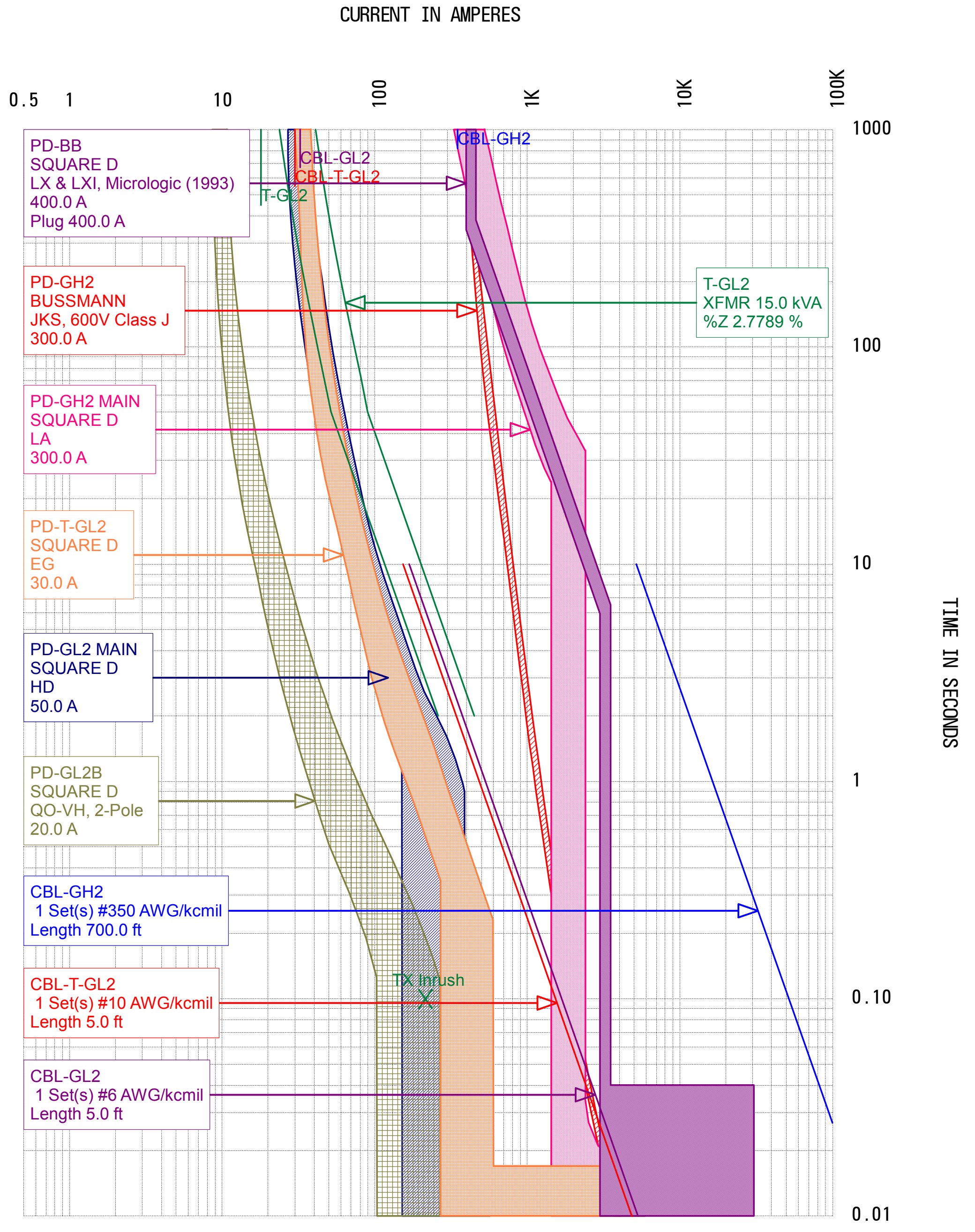
05-ELL2-E – There is good coordination between the overcurrent protective devices. There is an overlap of the trip curves for the transformer feeder breaker and the panelboard main breaker but this does not constitute a lack of coordination since both circuit breakers serve the same load. The panel MLS main breaker will need to be adjusted up from it's current setting. The breaker curve will overlap the panel MLS feeder breaker but this does not constitute a lack of coordination since both circuit breakers serve the same load.

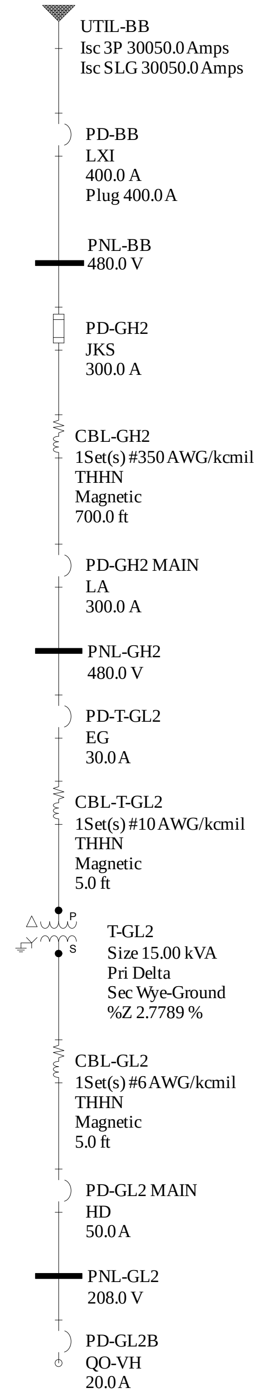
06-EL2-E – There is good coordination between the overcurrent protective devices. There is an overlap of the trip curves for the transformer feeder breaker and the panelboard main breaker but this does not constitute a lack of coordination since both circuit breakers serve the same load.

07-EL2-N – There is good coordination between the overcurrent protective devices. There is an overlap of the trip curves for the transformer feeder breaker and the panelboard main breaker but this does not constitute a lack of coordination since both circuit breakers serve the same load.

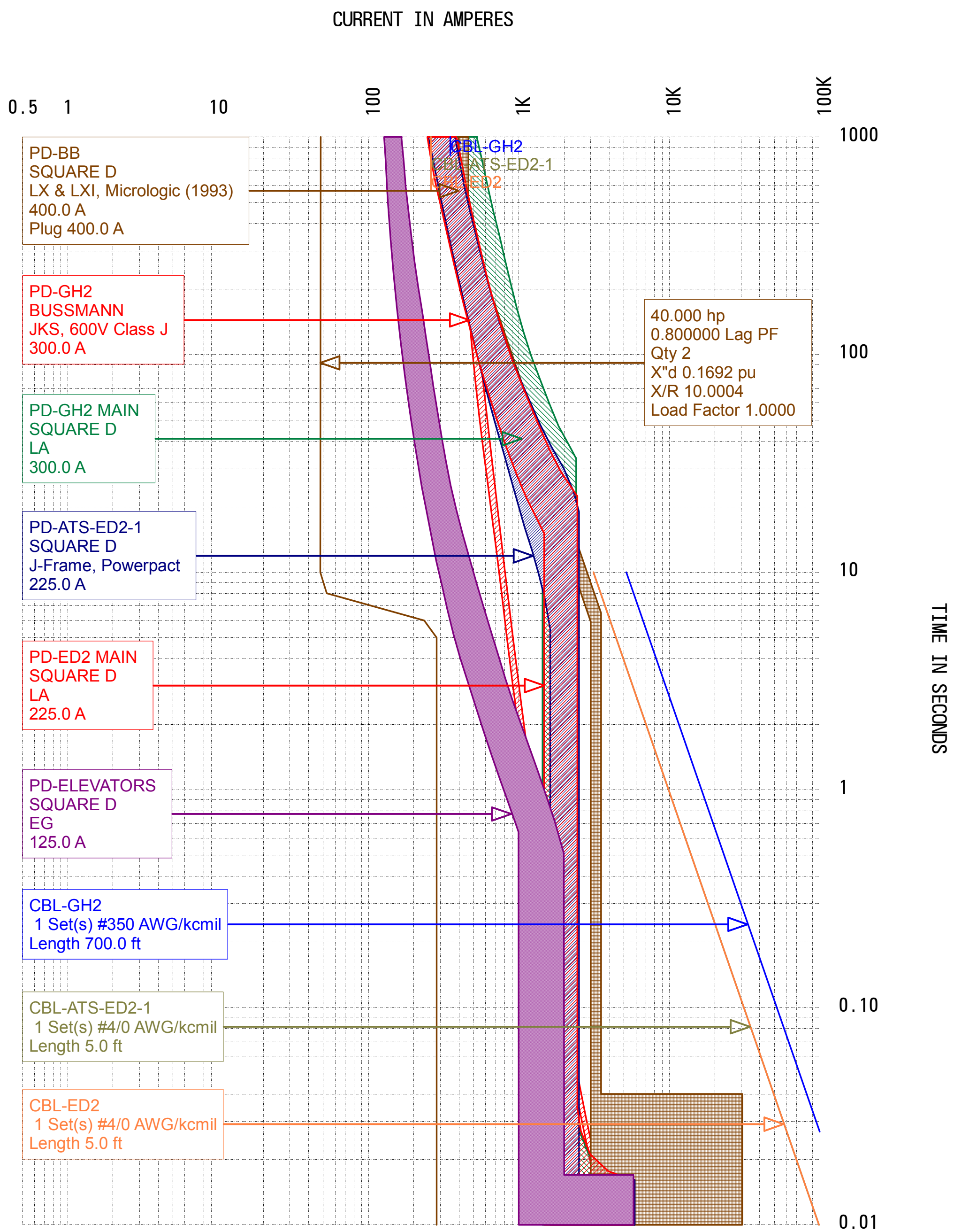
Nashville VA Parking Garage Static Trip Circuit Breaker Settings												
Protective Device	Panel/ Switchboard	Voltage	Manufacturer	Frame Description	Frame Size	Sensor	Plug	LTPU	LTD	STPU	STD (I^T)	INST
PD-BB	PNL-BB	480	SQUARE D	LXI	400	400	400	1.0 (400A)	14	8 (3200A)	0.1	8 (3200A)
PD-E SWBD MAIN	E-SWBD	480	GE	TC	2,500	2,500	2,500	1 (2500A)	2	4 (10000A)	Max (I^2t In)	7 (17500A)
PD-ATS-11-E	E-SWBD	480	GE	TC	800	400	250	1 (250A)	4	9 (2250A)	Min (I^2t Out)	15 (3750A)
PD-ATS-11-N	E-SWBD	480	GE	TC	800	400	250	1 (250A)	4	9 (2250A)	Min (I^2t Out)	15 (3750A)
PD-N SWBD MAIN	N-SWBD	480	GE	TC	2,500	2,500	2,500	1 (2500A)	1	1.5 (3750A)	Int (I^2t Out)	9 (22500A)
PD-NED	E-SWBD	480	GE	TC	800	400	400	1 (400A)	4	9 (3600A)	Min (I^2t Out)	10 (4000A)

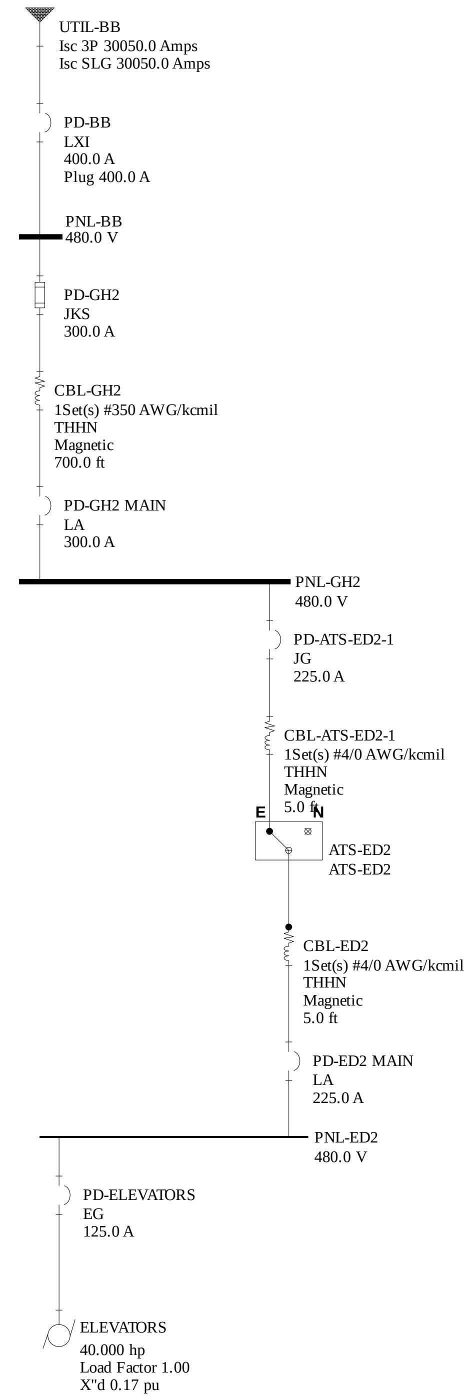
Nashville VA Parking Garage Adustable Thermal Magnetic Molded Case Circuit Breaker Settings							
Prot Dev	**Panel/Switchboard**	**Amps Frame**	**Manufacturer**	**Type**	**Amps Sensor/Plug**	**Sensor Type**	**Instantaneous Trip**
PD-ATS-ED2-1	PNL-GH2	250	SQUARE D	JG	225	J-Frame, Powerpact	INST (5-10 x Trip) 9.00
PD-ATS-ED2-2	PNL-NED	250	SQUARE D	JG	225	J-Frame, Powerpact	INST (5-10 x Trip) High
PD-ED2 MAIN	PNL-ED2	225	SQUARE D	LA	225	LA	INST 4
PD-GH2 MAIN	PNL-GH2	400	SQUARE D	LA	300	LA	INST 2
PD-MLS MAIN	PNL-MLS	400	GE	TLB4	250	TLB4	INST (4.5-10 x Trip) HI



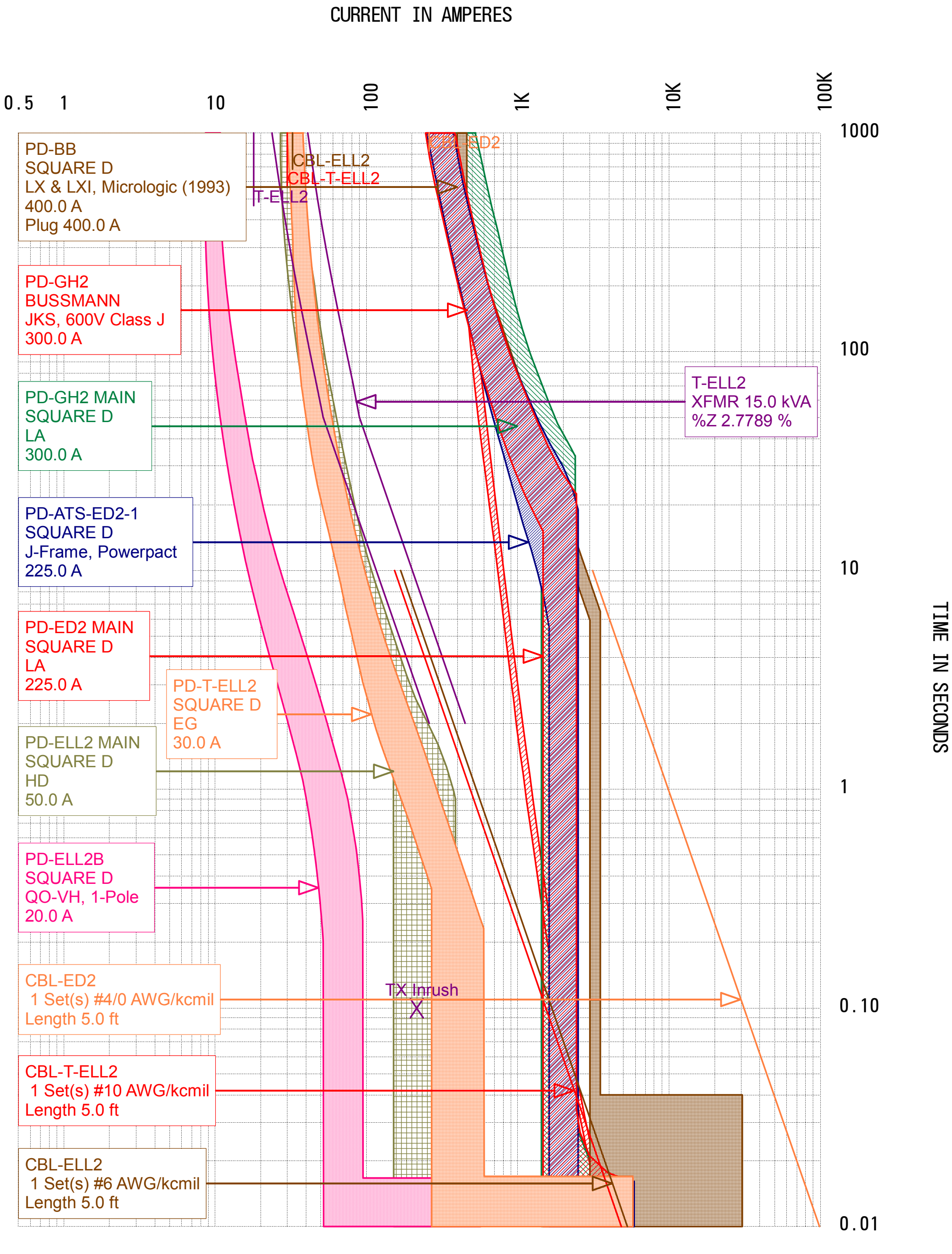


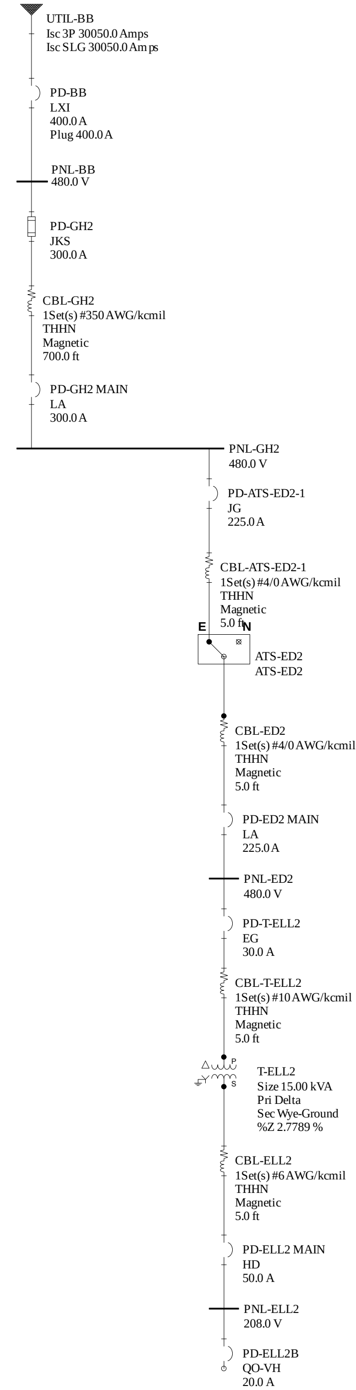
TCC: 01-GL2 Current Scale x 1 Reference Voltage: 480 January 15, 2012



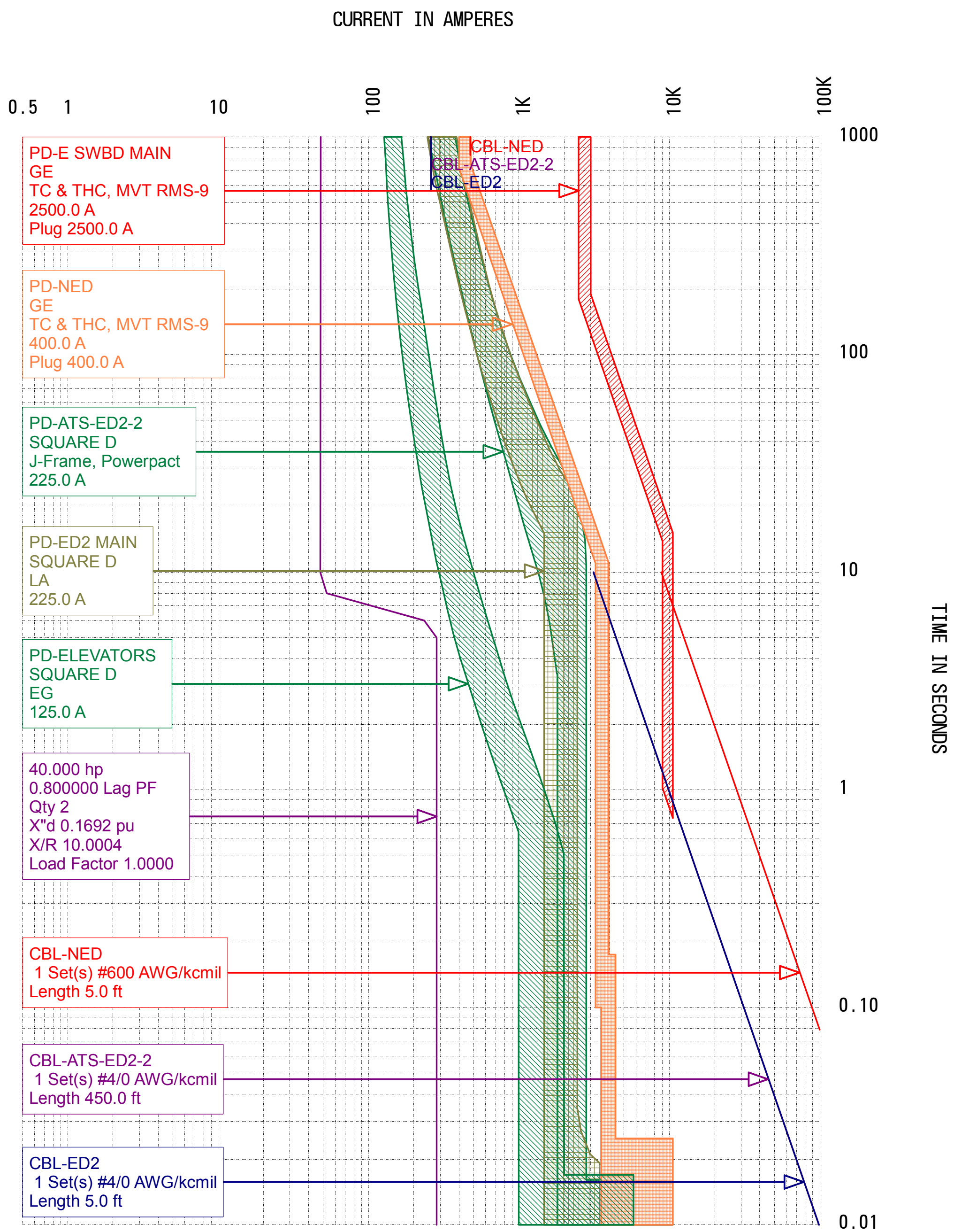


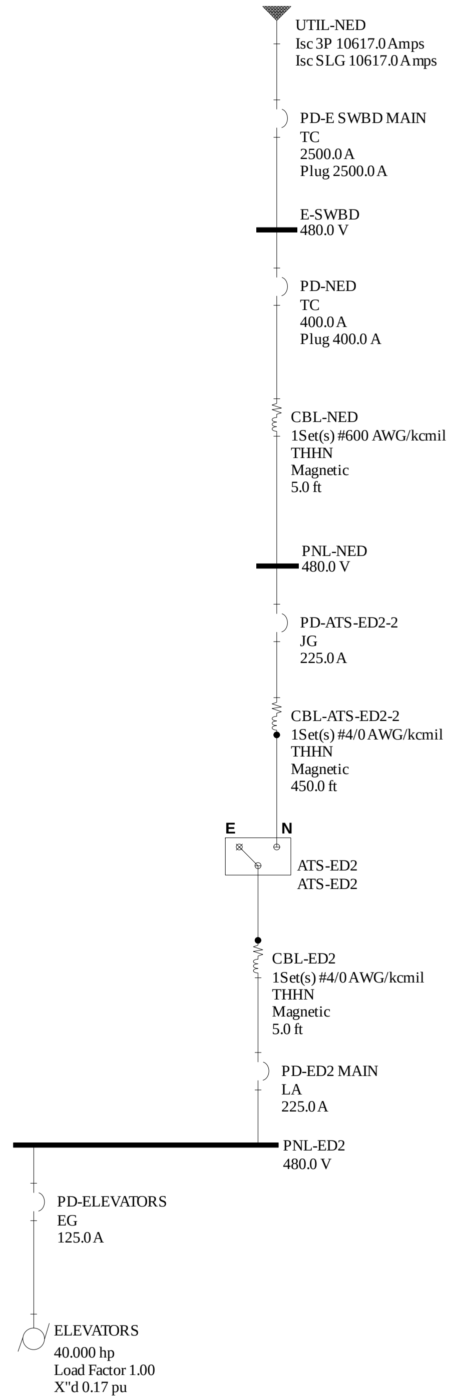
TCC: 02-ELEV-N   Current Scale x 1   Reference Voltage: 480   January 15, 2012





TCC: 03-ELL2-N Current Scale x 1 Reference Voltage: 480 January 15, 2012





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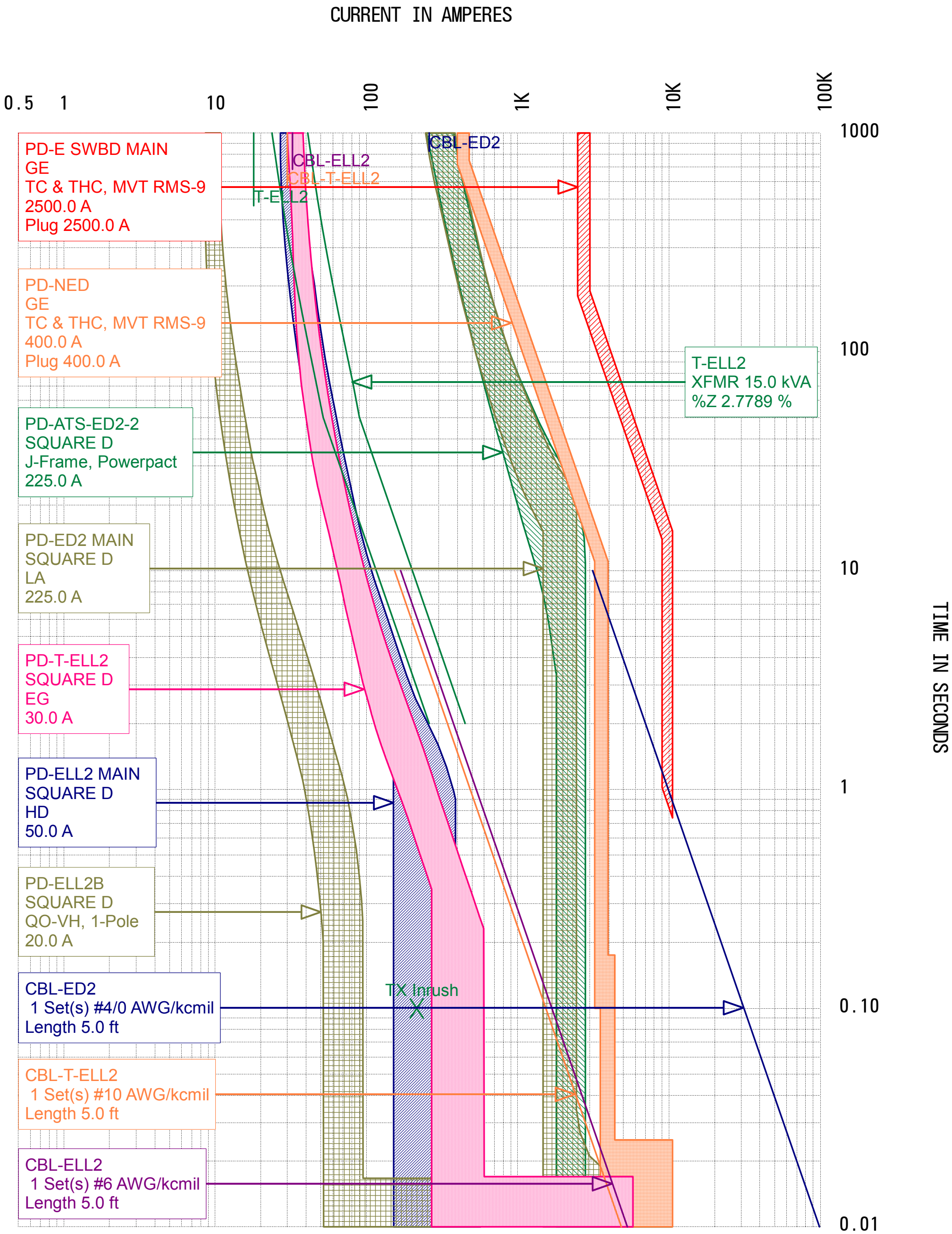

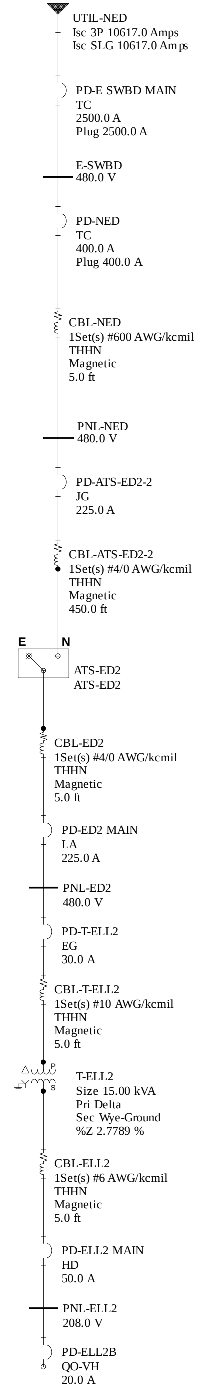

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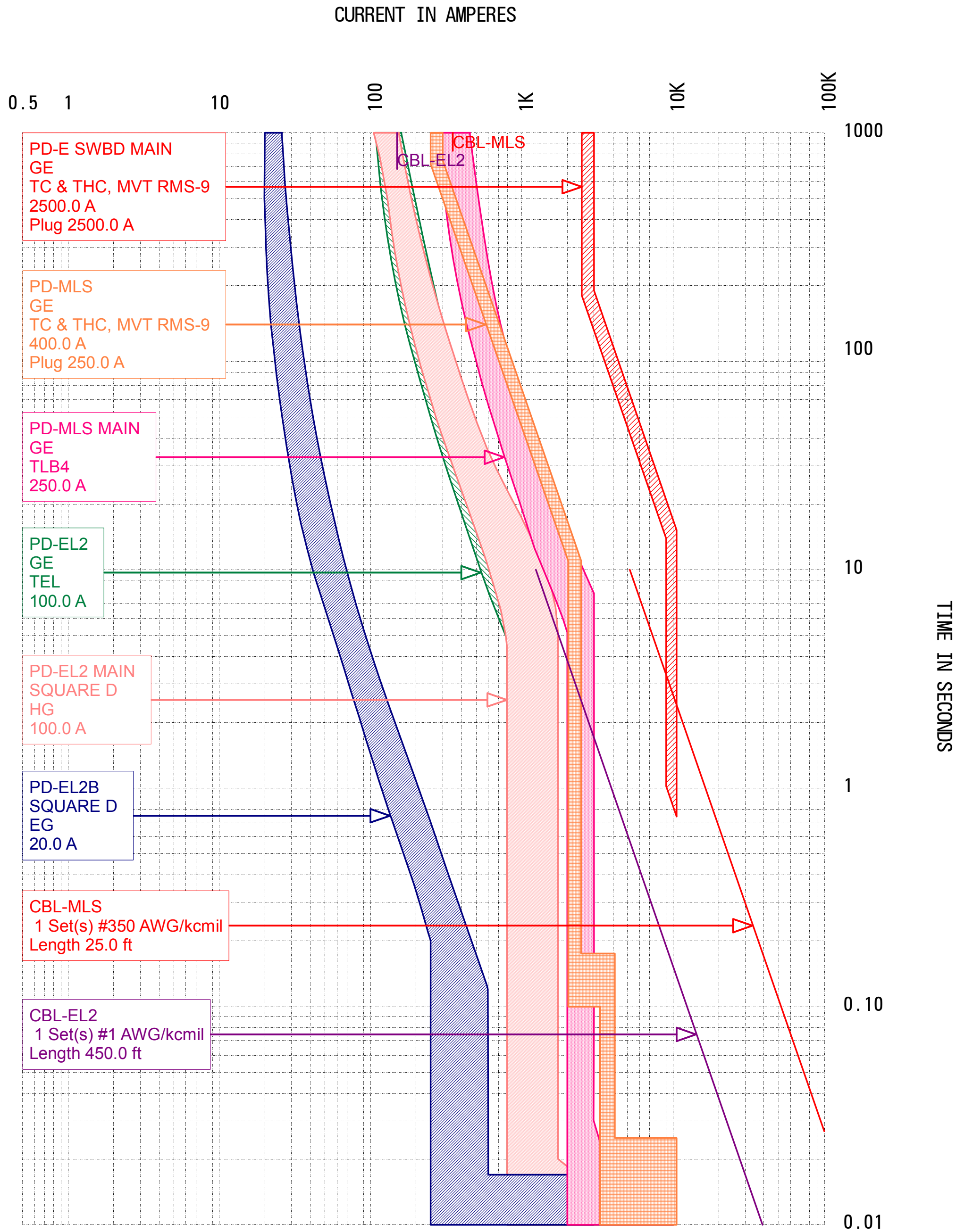

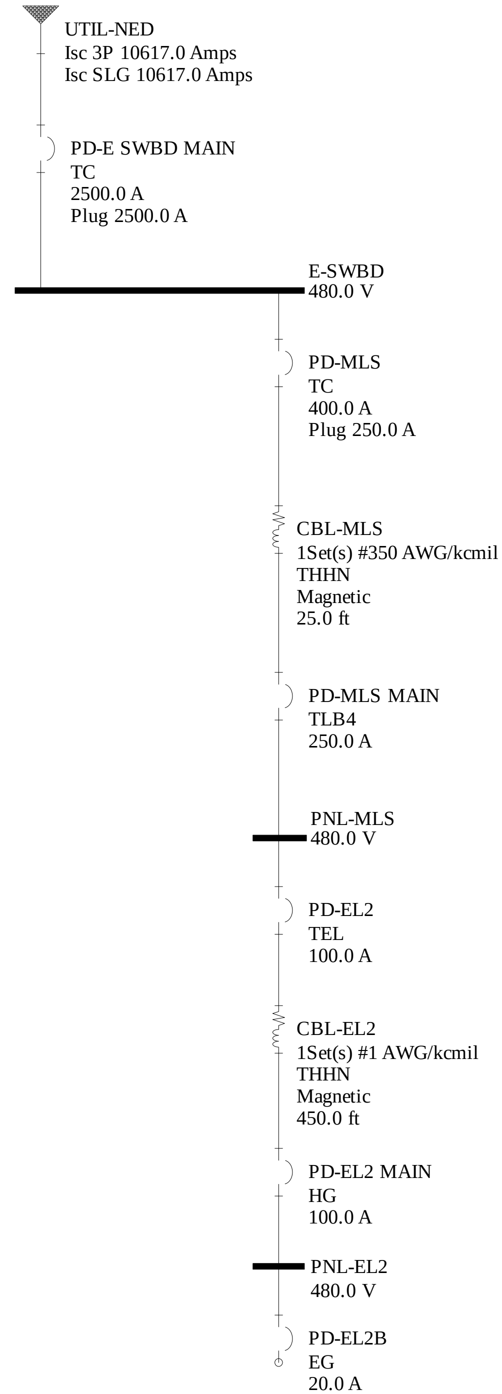

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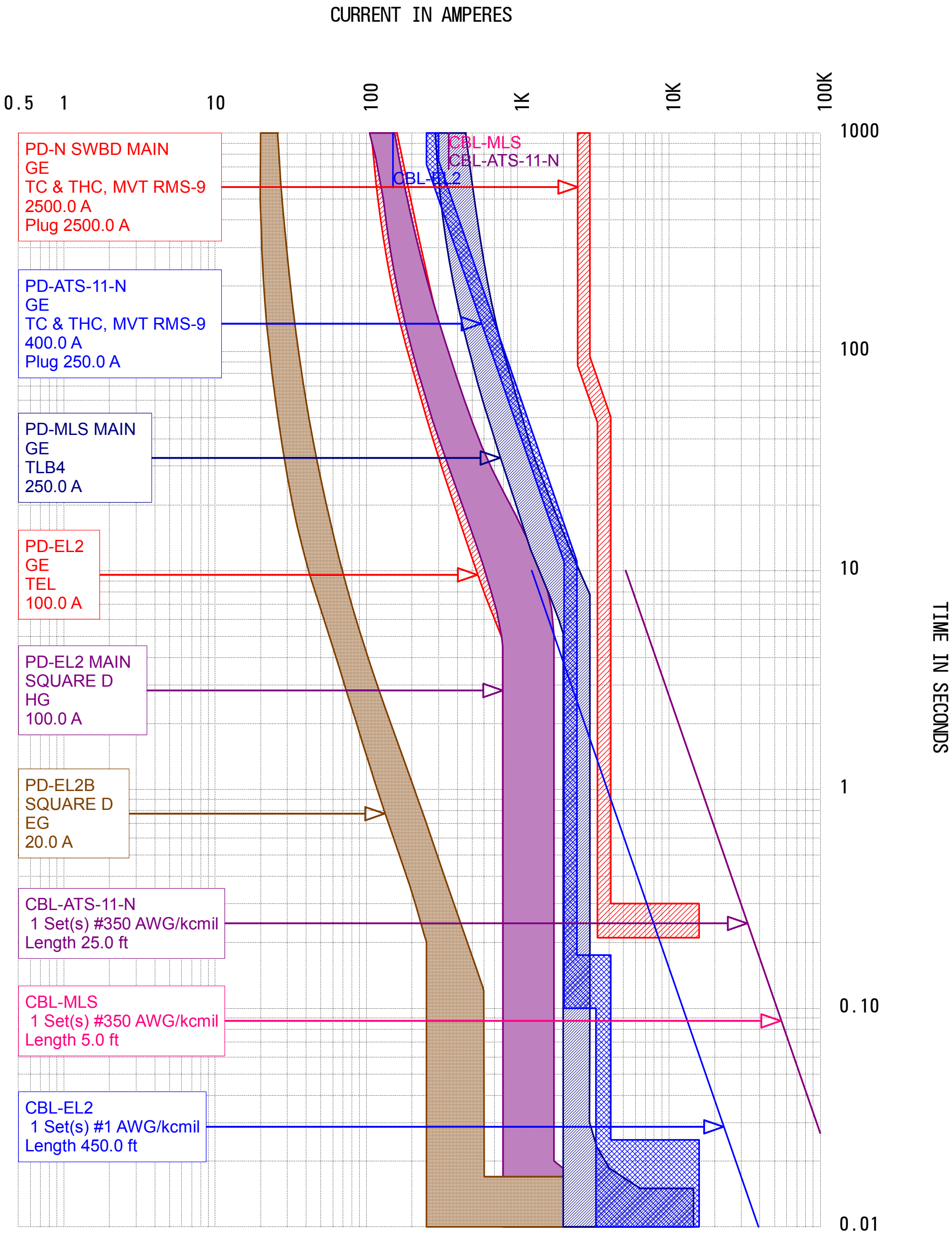

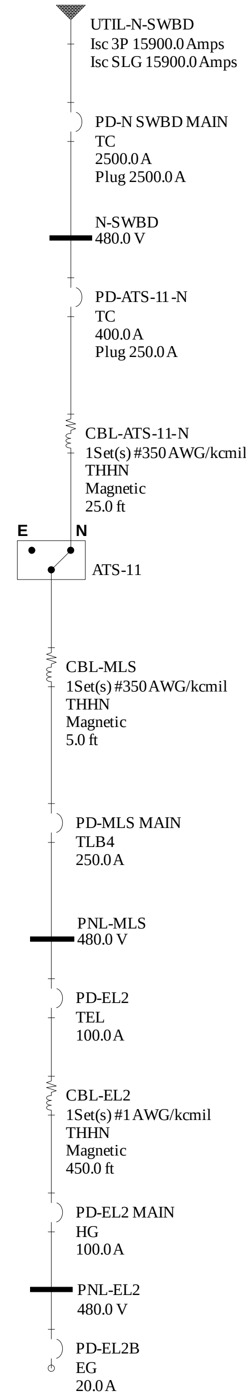

TCC: 07-EL2-N   Current Scale x 1   Reference Voltage: 480   January 30, 2012

Study Methodology

Fault-Current Calculation

Fault-Current Study

The fault-current study calculates the fault current for a bolted three-phase fault condition. This represents a “worst-case” condition resulting in maximum thermal and mechanical stress in the system.

Motor Contributions

In the fault-current studies, all motors are assumed to be running and are assumed to contribute fault current directly to the bus to which they are connected. Motor subtransient impedences are assumed to be in accordance with the ANSI/IEEE Standard 141-186. For simplification, the motors have been shown connected directly to the bus. This errs on the side of conservative with the fault current results.

Conductor Properties

The conductor properties were obtained from ANSI/IEEE Standard 242-1986.

Software

The electrical system was modeled and the calculations performed using PowerTools Version 6.5.1.8 (Build 4) by SKM Systems Analysis, Inc. The DAPPER System Studies comprehensive fault-current option was used for the fault-current calculations. The Arc Flash option was used for the arc-flash hazard assessment.

Coordination Study

The protective-device coordination study and coordination recommendations were developed in accordance with the IEEE Standard 242-1986. The TCC curves were produced with the PowerTools CAPTOR Time-Current Coordination module.

Specific Input Data Sources

Utility Source

The available fault current at the existing panelboards/switchboards were obtained from a previous study performed by GE in 1992 and another performed by Nash, Lipsey, Burch in 2000.

System Information

The feeder sizes and lengths, and the system topology were generated using the one-line drawings and information from Carter Concrete. The new equipment information was obtained from the equipment submittals.