WOOD COUNTY SOLAR PROJECT, LLC
COLLECTOR SYSTEM EMF STUDY

Prepared for:
WOOD COUNTY SOLAR PROJECT, LLC

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Revision Chart

Rev	Reason for Change	Author	Reviewer	Approved by	Issue Date
0	Released for Review	AR	AG	CP	02/27/2020

Sign-off Sheet

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Chris Pekar, Principal, Midwest, Environmental Services

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1.0 Summary

Wood County Solar Project, LLC (WCSP) is developing the Wood County Solar Project (Project), a 150-megawatt (MW) photovoltaic (PV) east-west tracking solar project to be located in the Township of Saratoga in Wood County, Wisconsin. This Collector System Electric and Magnetic Field (EMF) Study was conducted in support of WCSP's Application to the Public Service Commission of Wisconsin for a Certificate of Public Convenience and Necessity in accordance with Wis. Stat. § 196.491(3) and Wis. Admin Code § PSC 111.53). The major components of the proposed project will include solar modules, power conversion units, inverters, collection lines and 34.5/138 kilovolt (kV) collector substation.

Stantec's Ontario Office Power Group conducted the EMF study for the underground collection system. Base information required for the study was provided by WCSP and cable ampacity data from CYMCAP was also referred to for this study. Stantec conducted the study using the Bonneville Power Administration (BPA) Corona and Field Effects software. Where required, general underground cable orientations were assumed to smoothly perform the calculations.

2.0 Purpose and Project Description

The Project is a 150 MW Alternating Current (AC) rated solar generating facility proposed in Wood County, Wisconsin. The proposed underground collector system for the Project is designed to be rated at 34.5 kV and will consist of up to 6-feeders routed in parallel trenches, each approximately 24-inches to 32-inches apart. The collector system will connect the solar array to the Project substation. The entire collector system is scheduled to have buried underground lines.

The purpose of the study was to estimate the EMF strength created by the collector system for the Project. For the collector system, four (4) different scenarios were considered based on the number of feeders as detailed in Section 4-Collector System Scenarios.

3.0 Collector System Assumptions

3.1 UNDERGROUND SYSTEM

The entire collector system was assumed to have a 36-inch burial depth. The conductor diameter of 1,000 kcmil cable was assumed to be 1.117-inch. In addition to the 36-inches of the burial depth, 39.3-inches (1 meter) above ground (i.e. a total of 6.28-feet from the cable) was considered to calculate the magnetic field impact of the collector cables. The underground collection system will be buried in parallel trenches located approximately 24-inches or 32-inches apart from each other. For the purpose of these calculations, each Feeder is assumed to be installed in a trefoil configuration with the same phasing of rotation – A-B-C.

The following parameters were assumed for the cable ampacity calculation:

Ambient Soil Temperature	20 deg. C
Soil resistivity	0.9 deg. C-m/W
Conductor temperature	90 deg. C

The cables are assumed to be carrying full load current as per the cable ampacity data from CYMCAP (refer to Appendix B2).

1 Feeder	475 Amps
2 Feeders	475 Amps, each
3 Feeders	475 Amps, each
6 Feeders	475 or 422 Amps, each

4.0 Collector System Scenarios

Based on the above-mentioned details, it was determined that following scenarios should be studied.

UNDERGROUND SYSTEM	
Scenario 1	Single Feeder 1 in 1,000 kcmil cables (Typical buried collector circuit)
Scenario 2	Two (2) Feeders running parallel in 1,000 kcmil cables, each
Scenario 3	Three (3) Feeders running parallel in 1,000 kcmil cables, each
Scenario 4	Six (6) Feeders running parallel in 1,000 kcmil cables, each

5.0 Conclusion

The maximum magnetic field strength estimated near or at the centerline of the trench was calculated and is summarized in the table below. Electric field intensity was not calculated for the underground scenarios in the analysis because it is canceled out due to the shielding by the metallic screen on the underground cables. In each scenario of underground cables at 30-feet from the centerline, the magnetic field was below 5 milli-Gauss (mG). Appendices A.1 to A.4 provides detailed results for the four underground cable scenarios.

UNDERGROUND (UG) CABLES	MAXIMUM MAGNETIC FIELD (mGauss)
Scenario 1: 1 UG cable	17.41
Scenario 2: 2 parallel UG cables	30.38
Scenario 3: 3 parallel UG cables	41.62
Scenario 4: 6 parallel UG cables	46.93

By way of comparison, a typical electric blanket gives off 0.25 kV/m and a typical microwave gives off 60 mG.

Appendix A – Detailed Results for Collector System Scenarios

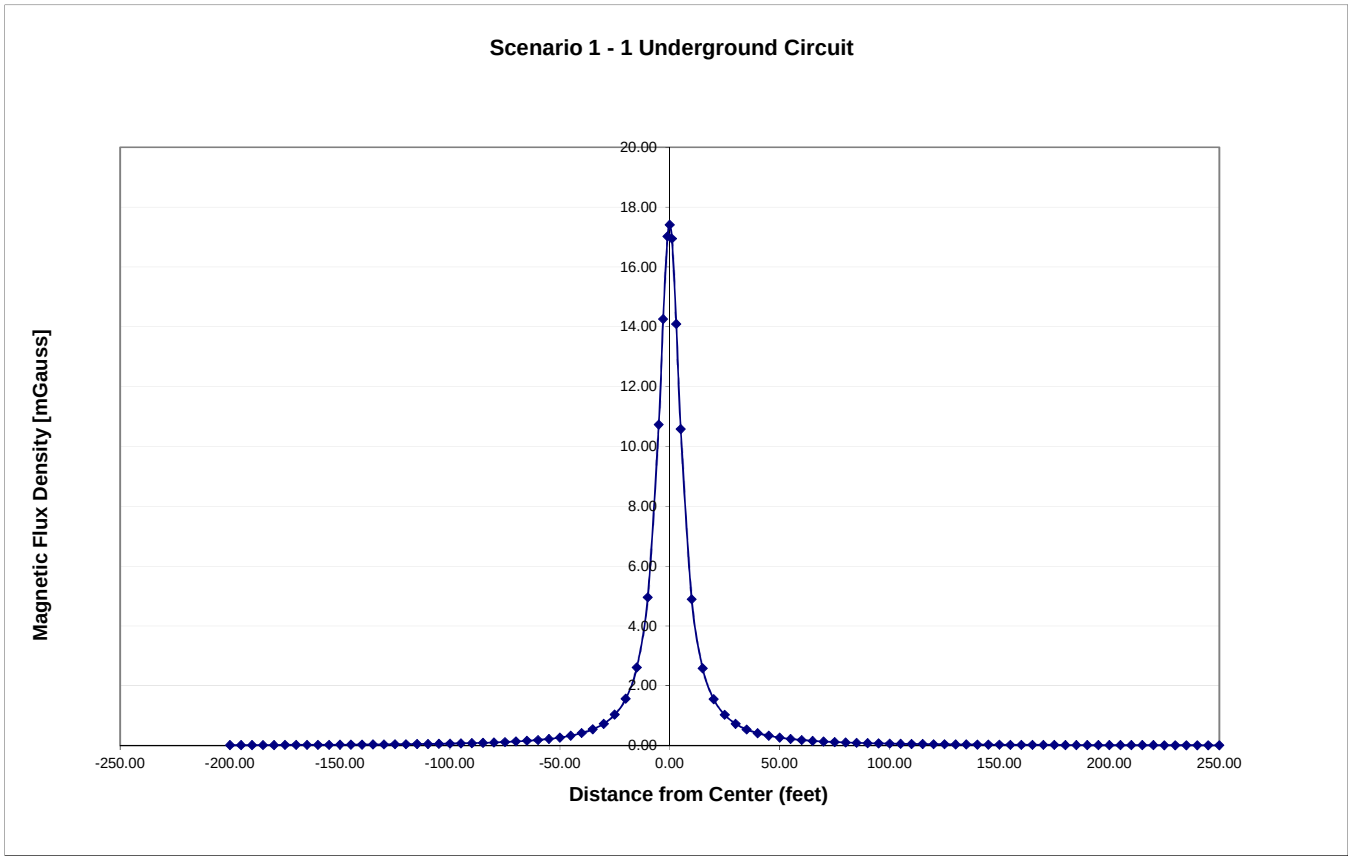
A.1 SCENARIO 1: SINGLE FEEDER – UNDERGROUND CABLE

Scenario 1 1 Underground Circuit
Cable 1000kcmil
Electromagnetic Field Calculation

Bundle	x-feet	y-feet	amps	phase	line name
1	-0.0925	9.66	475	0	Circuit 1
2	0	9.46	475	120	
3	-0.0925	9.66	475	240	

Dist - ft	Vert	**milligauss**
-200	3.28	0.01716
-195	3.28	0.01805
-190	3.28	0.01901
-185	3.28	0.02005
-180	3.28	0.02118
-175	3.28	0.02240
-170	3.28	0.02374
-165	3.28	0.02520
-160	3.28	0.02680
-155	3.28	0.02855
-150	3.28	0.03048
-145	3.28	0.03262
-140	3.28	0.03498
-135	3.28	0.03762
-130	3.28	0.04056
-125	3.28	0.04387
-120	3.28	0.04759
-115	3.28	0.05181
-110	3.28	0.05661
-105	3.28	0.06211
-100	3.28	0.06846
-95	3.28	0.07582
-90	3.28	0.08444
-85	3.28	0.09462
-80	3.28	0.10675
-75	3.28	0.12137
-70	3.28	0.13919
-65	3.28	0.16124
-60	3.28	0.18895
-55	3.28	0.22443
-50	3.28	0.27088
-45	3.28	0.33327
-40	3.28	0.41976
-35	3.28	0.54442
-30	3.28	0.73304
-25	3.28	1.03698
-20	3.28	1.56906
-15	3.28	2.61010
-10	3.28	4.95661
-5	3.28	10.73101
-3	3.28	14.25565
-1	3.28	17.01958
0	3.28	**17.41266**

Dist - ft	Vert	**milligauss**
1	3.28	16.94426
3	3.28	14.09738
5	3.28	10.58100
10	3.28	4.89187
15	3.28	2.58298
20	3.28	1.55595
25	3.28	1.02980
30	3.28	0.72873
35	3.28	0.54164
40	3.28	0.41787
45	3.28	0.33193
50	3.28	0.26989
55	3.28	0.22369
60	3.28	0.18837
65	3.28	0.16078
70	3.28	0.13883
75	3.28	0.12107
80	3.28	0.10651
85	3.28	0.09442
90	3.28	0.08427
95	3.28	0.07568
100	3.28	0.06833
105	3.28	0.06200
110	3.28	0.05651
115	3.28	0.05172
120	3.28	0.04752
125	3.28	0.04380
130	3.28	0.04051
135	3.28	0.03757
140	3.28	0.03494
145	3.28	0.03258
150	3.28	0.03044
155	3.28	0.02852
160	3.28	0.02676
165	3.28	0.02517
170	3.28	0.02371
175	3.28	0.02238
180	3.28	0.02116
185	3.28	0.02003
190	3.28	0.01899
195	3.28	0.01803
200	3.28	0.01714


Scenario 1 - 1 Underground Circuit
Magnetic Flux Density [mGauss]
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-250.00
-200.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
250.00
Distance from Center (feet)

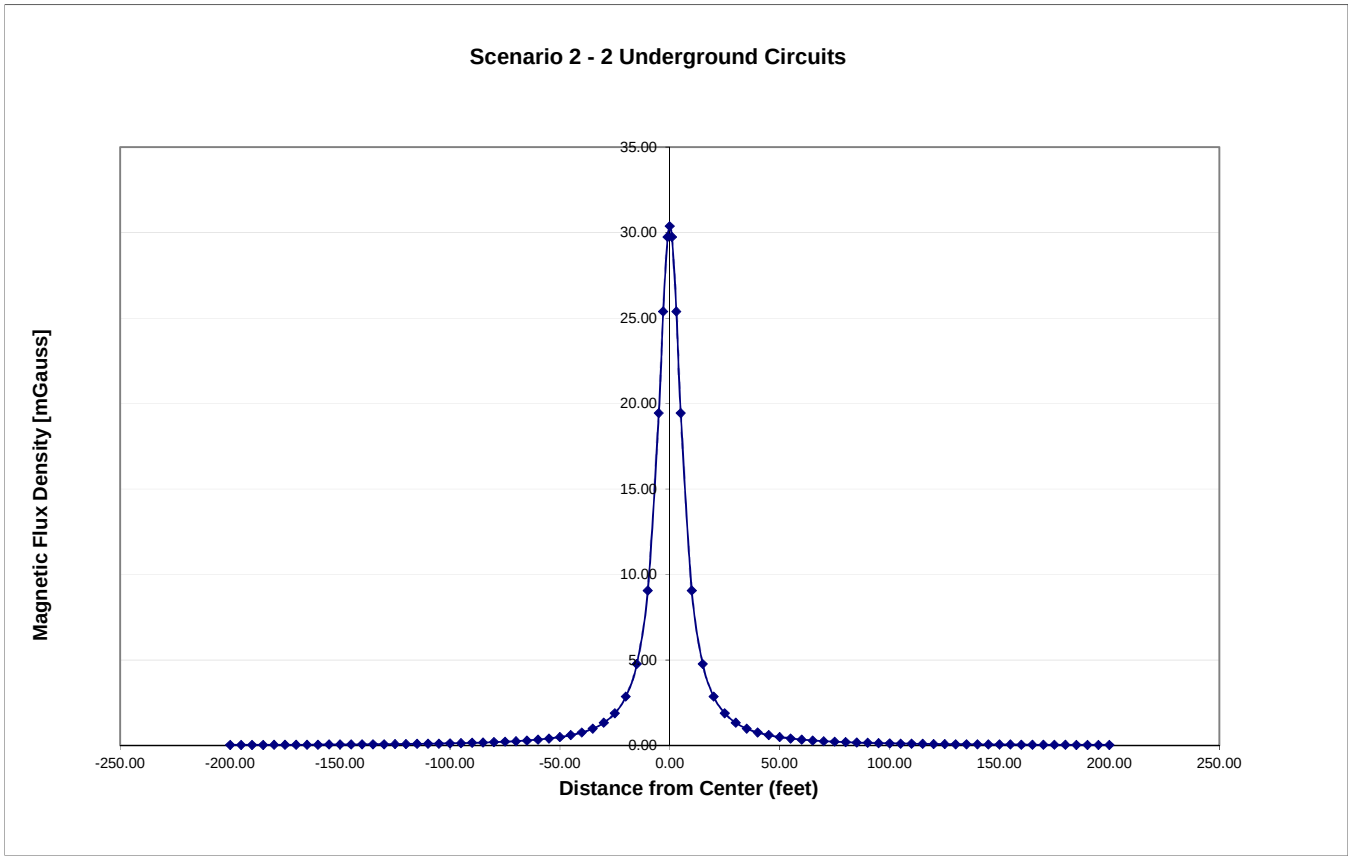
A.2 SCENARIO 2: TWO (2) FEEDERS – UNDERGROUND CABLES

Scenario 2 2 Underground Circuits
Cable 1000kcmil
Electromagnetic Field Calculation

Bundle	x-feet	y-feet	amps	phase	line name
1	-0.9075	9.66	475	0	Circuit 1
2	-1	9.46	475	120	
3	-1.0925	9.66	475	240	
4	0.9075	9.66	475	0	Circuit 2
5	1	9.46	475	120	
6	1.0925	9.66	475	240	

Dist - ft	Vert	**milligauss**
-200	3.28	0.03113
-195	3.28	0.03275
-190	3.28	0.03449
-185	3.28	0.03638
-180	3.28	0.03843
-175	3.28	0.04065
-170	3.28	0.04307
-165	3.28	0.04572
-160	3.28	0.04862
-155	3.28	0.05180
-150	3.28	0.05531
-145	3.28	0.05918
-140	3.28	0.06347
-135	3.28	0.06825
-130	3.28	0.07359
-125	3.28	0.07959
-120	3.28	0.08634
-115	3.28	0.09399
-110	3.28	0.10270
-105	3.28	0.11268
-100	3.28	0.12419
-95	3.28	0.13755
-90	3.28	0.15319
-85	3.28	0.17165
-80	3.28	0.19365
-75	3.28	0.22017
-70	3.28	0.25250
-65	3.28	0.29250
-60	3.28	0.34277
-55	3.28	0.40716
-50	3.28	0.49144
-45	3.28	0.60468
-40	3.28	0.76173
-35	3.28	0.98818
-30	3.28	1.33111
-25	3.28	1.88437
-20	3.28	2.85489
-15	3.28	4.75973
-10	3.28	9.06492
-5	3.28	19.44733
-3	3.28	25.38815
-1	3.28	29.74277
0	3.28	**30.37648**

Dist - ft	Vert	**milligauss**
1	3.28	29.74277
3	3.28	25.38815
5	3.28	19.44733
10	3.28	9.06492
15	3.28	4.75973
20	3.28	2.85489
25	3.28	1.88437
30	3.28	1.33111
35	3.28	0.98818
40	3.28	0.76173
45	3.28	0.60468
50	3.28	0.49144
55	3.28	0.40716
60	3.28	0.34277
65	3.28	0.29250
70	3.28	0.25250
75	3.28	0.22017
80	3.28	0.19365
85	3.28	0.17165
90	3.28	0.15319
95	3.28	0.13755
100	3.28	0.12419
105	3.28	0.11268
110	3.28	0.10270
115	3.28	0.09399
120	3.28	0.08634
125	3.28	0.07959
130	3.28	0.07359
135	3.28	0.06825
140	3.28	0.06347
145	3.28	0.05918
150	3.28	0.05531
155	3.28	0.05180
160	3.28	0.04862
165	3.28	0.04572
170	3.28	0.04307
175	3.28	0.04065
180	3.28	0.03843
185	3.28	0.03638
190	3.28	0.03449
195	3.28	0.03275
200	3.28	0.03113


Scenario 2 - 2 Underground Circuits
Magnetic Flux Density [mGauss]
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-250.00
-200.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
250.00
Distance from Center (feet)

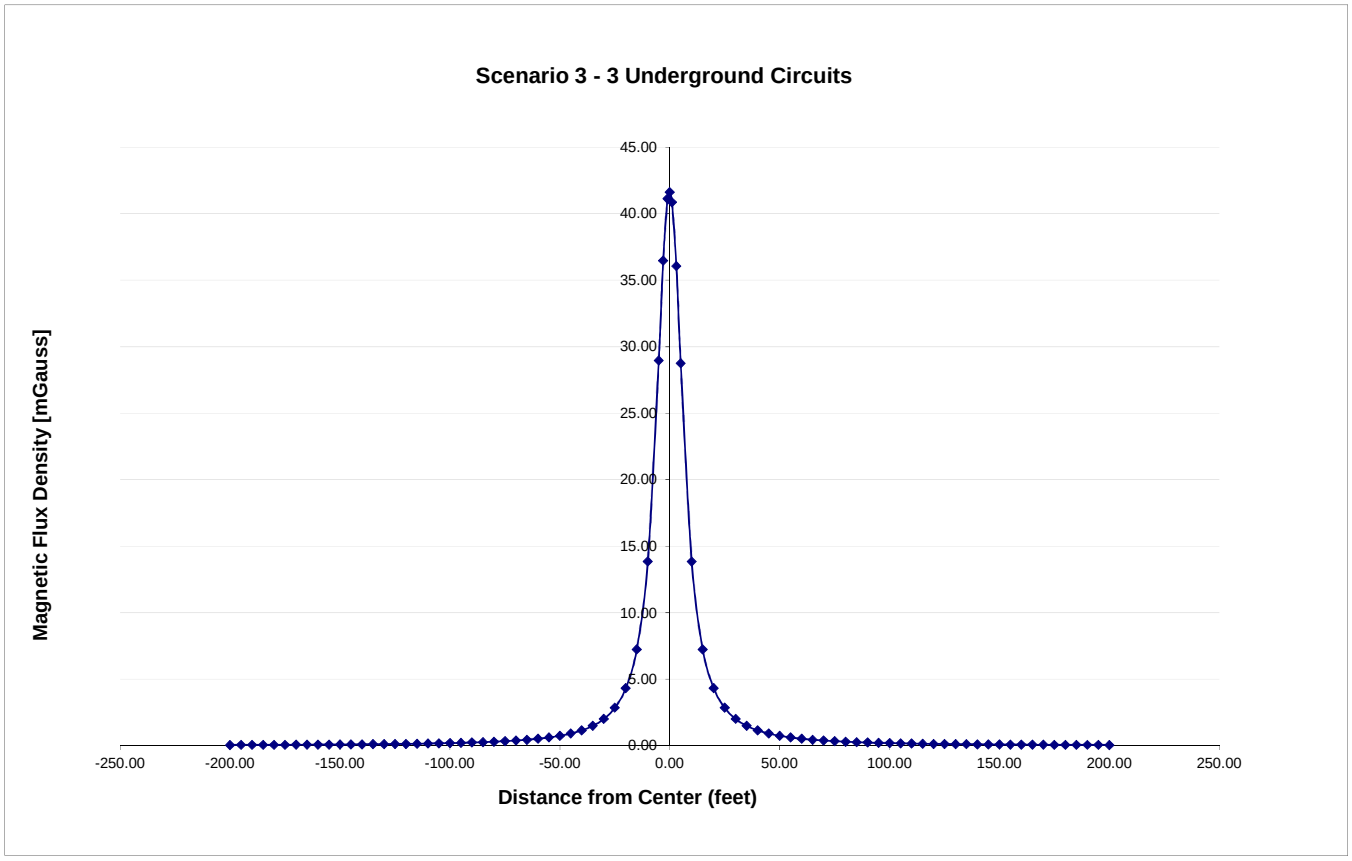
A.3 SCENARIO 3: THREE (3) FEEDERS – UNDERGROUND CABLES

Scenario 3 3 Underground Circuits
Cable 1000kcmil
Electromagnetic Field Calculation

Bundle	x-feet	y-feet	amps	phase	line name
1	-1.9075	9.66	475	0	Circuit 1
2	-2	9.46	475	120	
3	-2.0925	9.66	475	240	
4	-0.0925	9.66	475	0	Circuit 2
5	0	9.46	475	120	
6	0.0925	9.66	475	240	
7	1.9075	9.66	475	0	Circuit 3
8	2	9.46	475	120	
9	2.0925	9.66	475	240	

Dist - ft	Vert	**milligauss**
-200	3.28	0.04670
-195	3.28	0.04913
-190	3.28	0.05174
-185	3.28	0.05458
-180	3.28	0.05765
-175	3.28	0.06099
-170	3.28	0.06462
-165	3.28	0.06859
-160	3.28	0.07294
-155	3.28	0.07772
-150	3.28	0.08298
-145	3.28	0.08879
-140	3.28	0.09524
-135	3.28	0.10241
-130	3.28	0.11042
-125	3.28	0.11942
-120	3.28	0.12955
-115	3.28	0.14104
-110	3.28	0.15411
-105	3.28	0.16910
-100	3.28	0.18638
-95	3.28	0.20644
-90	3.28	0.22993
-85	3.28	0.25765
-80	3.28	0.29071
-75	3.28	0.33054
-70	3.28	0.37913
-65	3.28	0.43925
-60	3.28	0.51485
-55	3.28	0.61171
-50	3.28	0.73857
-45	3.28	0.90914
-40	3.28	1.14593
-35	3.28	1.48782
-30	3.28	2.00654
-25	3.28	2.84570
-20	3.28	4.32375
-15	3.28	7.24072
-10	3.28	13.84625
-5	3.28	28.97249
-3	3.28	36.47416
-1	3.28	41.11947
0	3.28	**41.62390**

Dist - ft	Vert	**milligauss**
1	3.28	40.85611
3	3.28	36.06536
5	3.28	28.74919
10	3.28	13.83154
15	3.28	7.24045
20	3.28	4.32406
25	3.28	2.84588
30	3.28	2.00663
35	3.28	1.48787
40	3.28	1.14596
45	3.28	0.90916
50	3.28	0.73858
55	3.28	0.61172
60	3.28	0.51486
65	3.28	0.43926
70	3.28	0.37913
75	3.28	0.33054
80	3.28	0.29071
85	3.28	0.25765
90	3.28	0.22993
95	3.28	0.20644
100	3.28	0.18638
105	3.28	0.16910
110	3.28	0.15412
115	3.28	0.14104
120	3.28	0.12955
125	3.28	0.11942
130	3.28	0.11042
135	3.28	0.10241
140	3.28	0.09524
145	3.28	0.08879
150	3.28	0.08298
155	3.28	0.07772
160	3.28	0.07294
165	3.28	0.06859
170	3.28	0.06462
175	3.28	0.06099
180	3.28	0.05765
185	3.28	0.05458
190	3.28	0.05174
195	3.28	0.04913
200	3.28	0.04670


Scenario 3 - 3 Underground Circuits
Magnetic Flux Density [mGauss]
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-250.00
-200.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
250.00
Distance from Center (feet)

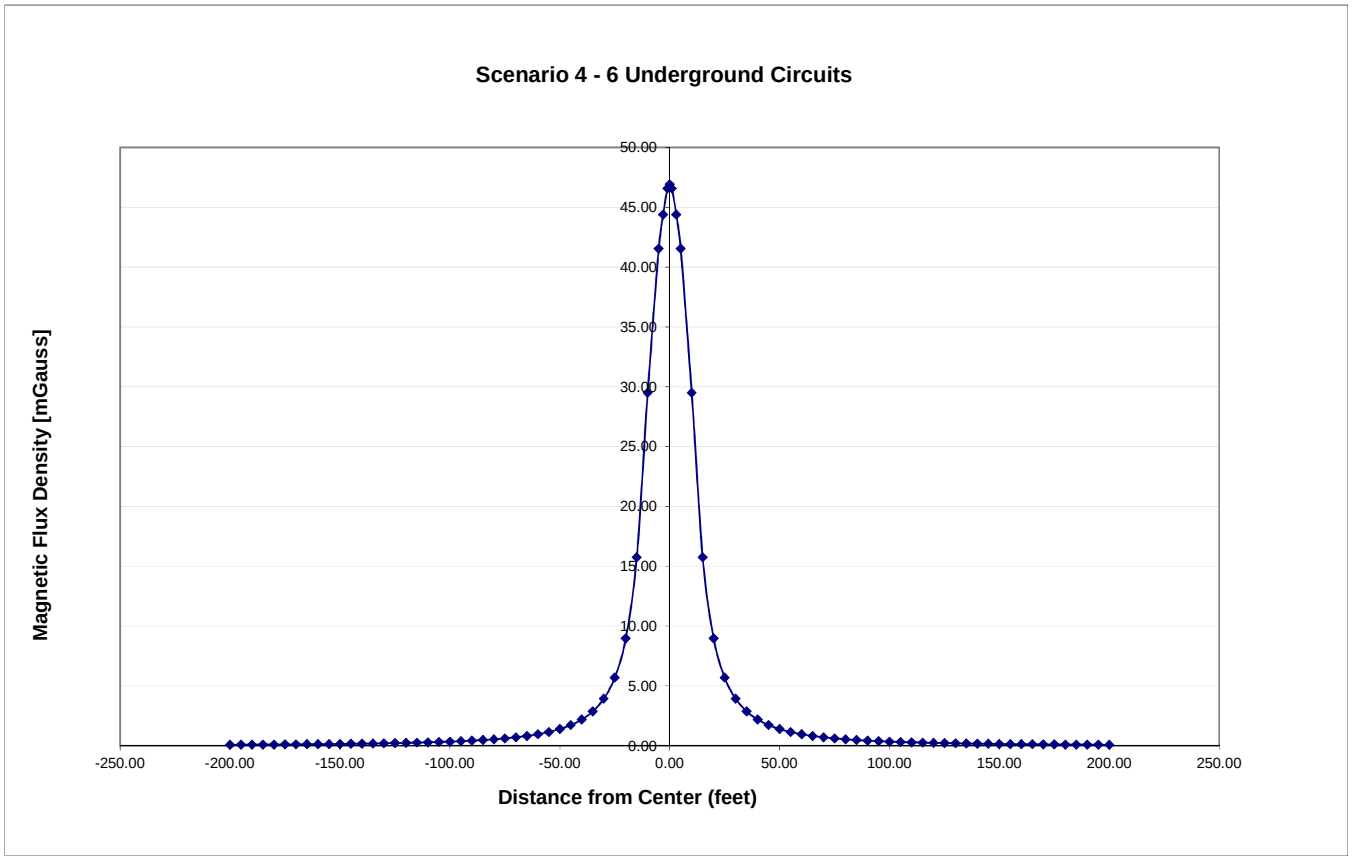
A.4 SCENARIO 4: SIX (6) FEEDERS – UNDERGROUND CABLES

Scenario 4 6 Underground Circuits
Cable 1000kcmil
Electromagnetic Field Calculation

Bundle	x-feet	y-feet	amps	phase	line name
1	-6.7592	9.66	475	0	Circuit 1
2	-6.6667	9.46	475	120	
3	-6.5742	9.66	475	240	
4	-4.0925	9.66	422	0	Circuit 2
5	-4	9.46	422	120	
6	-3.9075	9.66	422	240	
7	-1.4258	9.66	422	0	Circuit 3
8	-1.3333	9.46	422	120	
9	-1.2408	9.66	422	240	
10	1.4258	9.66	422	0	Circuit 4
11	1.3333	9.46	422	120	
12	1.2408	9.66	422	240	
13	4.0925	9.66	422	0	Circuit 5
14	4	9.46	422	120	
15	3.9075	9.66	422	240	
16	6.7592	9.66	475	0	Circuit 6
17	6.6667	9.46	475	120	
18	6.5742	9.66	475	240	

Dist - ft	Vert	**milligauss**
-200	3.28	0.08658
-195	3.28	0.09108
-190	3.28	0.09594
-185	3.28	0.10120
-180	3.28	0.10691
-175	3.28	0.11311
-170	3.28	0.11987
-165	3.28	0.12725
-160	3.28	0.13533
-155	3.28	0.14422
-150	3.28	0.15400
-145	3.28	0.16482
-140	3.28	0.17682
-135	3.28	0.19017
-130	3.28	0.20511
-125	3.28	0.22187
-120	3.28	0.24078
-115	3.28	0.26221
-110	3.28	0.28664
-105	3.28	0.31466
-100	3.28	0.34699
-95	3.28	0.38458
-90	3.28	0.42863
-85	3.28	0.48072
-80	3.28	0.54293
-75	3.28	0.61806
-70	3.28	0.70996
-65	3.28	0.82403
-60	3.28	0.96804
-55	3.28	1.15347
-50	3.28	1.39791
-45	3.28	1.72941
-40	3.28	2.19486
-35	3.28	2.87759
-30	3.28	3.93694
-25	3.28	5.70754
-20	3.28	8.97474
-15	3.28	15.74929
-10	3.28	29.49859
-5	3.28	41.54129
-3	3.28	44.38907
-1	3.28	46.58359
0	3.28	**46.92728**

Dist - ft	Vert	**milligauss**
1	3.28	46.58359
3	3.28	44.38907
5	3.28	41.54129
10	3.28	29.49859
15	3.28	15.74929
20	3.28	8.97474
25	3.28	5.70754
30	3.28	3.93694
35	3.28	2.87759
40	3.28	2.19486
45	3.28	1.72941
50	3.28	1.39791
55	3.28	1.15347
60	3.28	0.96804
65	3.28	0.82403
70	3.28	0.70996
75	3.28	0.61806
80	3.28	0.54293
85	3.28	0.48072
90	3.28	0.42863
95	3.28	0.38458
100	3.28	0.34699
105	3.28	0.31466
110	3.28	0.28664
115	3.28	0.26221
120	3.28	0.24078
125	3.28	0.22187
130	3.28	0.20511
135	3.28	0.19017
140	3.28	0.17682
145	3.28	0.16482
150	3.28	0.15400
155	3.28	0.14422
160	3.28	0.13533
165	3.28	0.12725
170	3.28	0.11987
175	3.28	0.11311
180	3.28	0.10691
185	3.28	0.10120
190	3.28	0.09594
195	3.28	0.09108
200	3.28	0.08658


Scenario 4 - 6 Underground Circuits
Magnetic Flux Density [mGauss]
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-250.00
-200.00
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00
200.00
250.00
Distance from Center (feet)

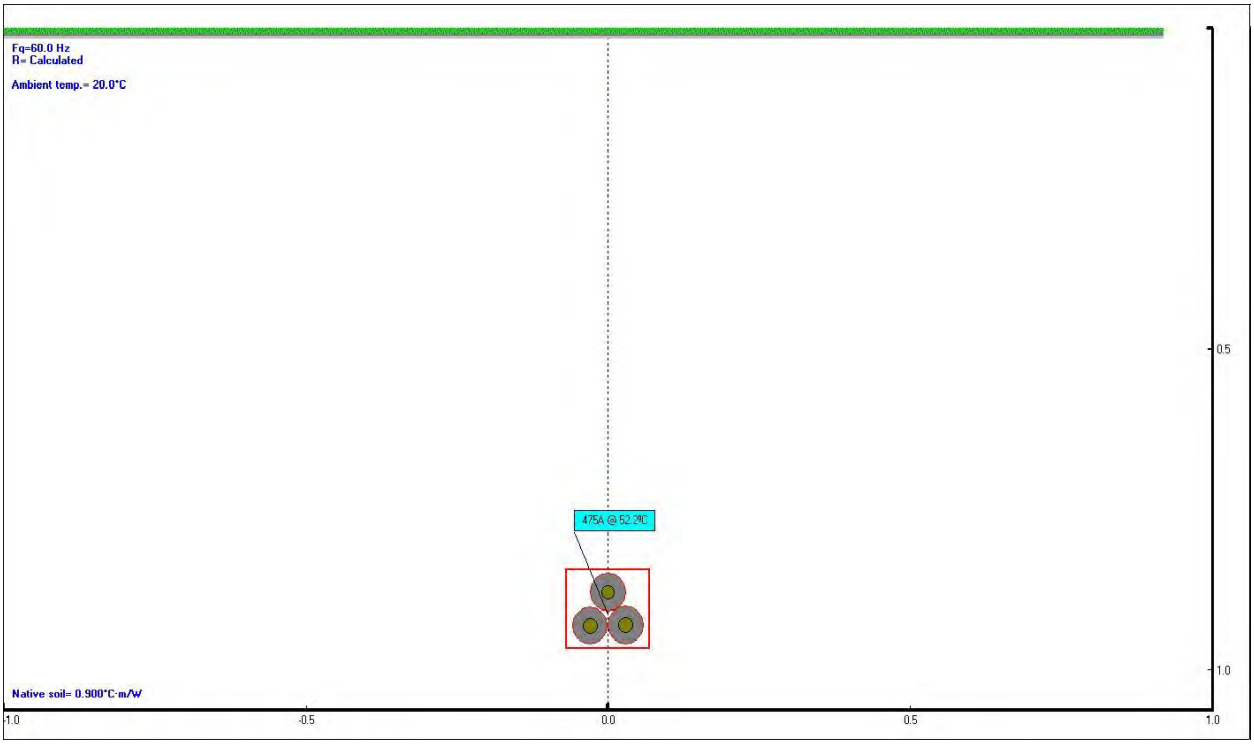
Appendix B – Reference Data

B.1 SCREENSHOTS OF CABLE AMPACITY SCENARIOS – CYMCAP

Installation Type:Directly Buried		
Ambient Soil Temperature at Installation Depth	[°C]	20.0
Native Soil Thermal Resistivity	[K.m/W]	0.9
Consider Non-Isothermal Earth Surface		No
Consider effect of soil dry out		No

Results Summary

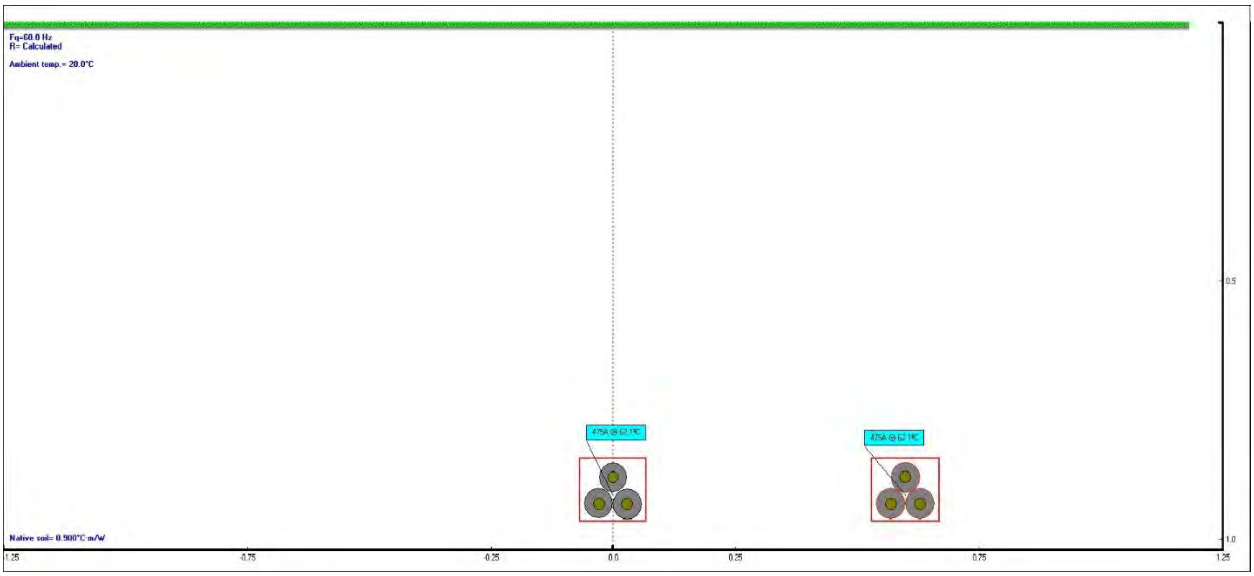
Cable No.	Cable ID	Circuit No.	Feeder ID	Cable Phase	Cable Frequency	Daily Load Factor	X coordinate [m]	Y coordinate [m]	Conductor temperature [°C]	Ampacity [A]
1	1C-1000-AL-1_1	1		A	60.0	1.0	-0.03	0.93	52.2	475.0
2	1C-1000-AL-1_1	1		B	60.0	1.0	0.03	0.93	52.2	475.0
3	1C-1000-AL-1_1	1		C	60.0	1.0	0.0	0.88	52.0	475.0



Installation Type:Directly Buried		
Ambient Soil Temperature at Installation Depth	[°C]	20.0
Native Soil Thermal Resistivity	[K.m/W]	0.9
Consider Non-Isothermal Earth Surface		No
Consider effect of soil dry out		No

Results Summary

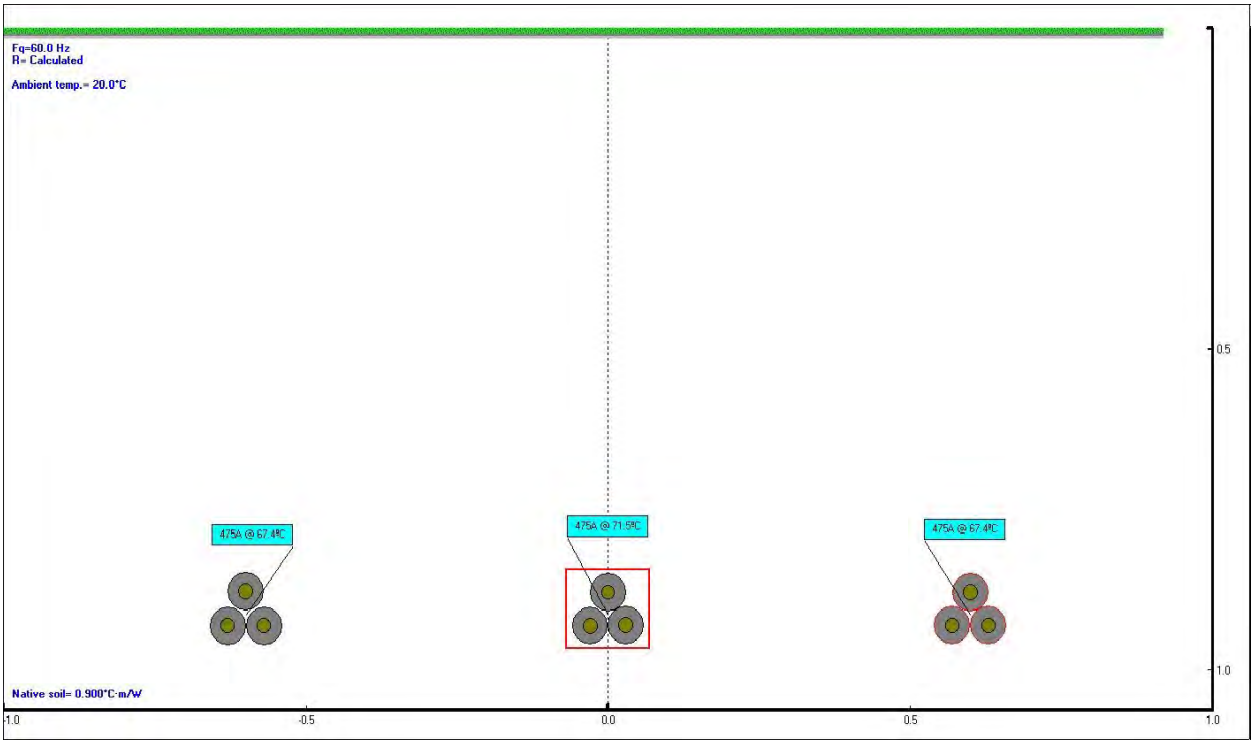
Cable No.	Cable ID	Circuit No.	Feeder ID	Cable Phase	Cable Frequency	Daily Load Factor	X coordinate [m]	Y coordinate [m]	Conductor temperature [°C]	Ampacity [A]
1	1C-1000-AL-1_1	1		A	60.0	1.0	-0.03	0.93	61.4	475.0
2	1C-1000-AL-1_1	1		B	60.0	1.0	0.03	0.93	62.1	475.0
3	1C-1000-AL-1_1	1		C	60.0	1.0	0.0	0.88	61.3	475.0
4	1C-1000-AL-1_1	2		A	60.0	1.0	0.57	0.93	62.1	475.0
5	1C-1000-AL-1_1	2		B	60.0	1.0	0.63	0.93	61.4	475.0
6	1C-1000-AL-1_1	2		C	60.0	1.0	0.6	0.88	61.3	475.0



Installation Type:Directly Buried		
Ambient Soil Temperature at Installation Depth	[°C]	20.0
Native Soil Thermal Resistivity	[K.m/W]	0.9
Consider Non-Isothermal Earth Surface		No
Consider effect of soil dry out		No

Results Summary

Cable No.	Cable ID	Circuit No.	Feeder ID	Cable Phase	Cable Frequency	Daily Load Factor	X coordinate [m]	Y coordinate [m]	Conductor temperature [°C]	Ampacity [A]
1	1C-1000-AL-1_1	1		A	60.0	1.0	-0.63	0.93	66.5	475.0
2	1C-1000-AL-1_1	1		B	60.0	1.0	-0.57	0.93	67.4	475.0
3	1C-1000-AL-1_1	1		C	60.0	1.0	-0.6	0.88	66.3	475.0
4	1C-1000-AL-1_1	2		A	60.0	1.0	-0.03	0.93	71.5	475.0
5	1C-1000-AL-1_1	2		B	60.0	1.0	0.03	0.93	71.5	475.0
6	1C-1000-AL-1_1	2		C	60.0	1.0	0.0	0.88	70.8	475.0
7	1C-1000-AL-1_1	3		A	60.0	1.0	0.57	0.93	67.4	475.0
8	1C-1000-AL-1_1	3		B	60.0	1.0	0.63	0.93	66.5	475.0
9	1C-1000-AL-1_1	3		C	60.0	1.0	0.6	0.88	66.3	475.0



Installation Type:Directly Buried

Ambient Soil Temperature at Installation Depth	[°C]	20.0
Native Soil Thermal Resistivity	[K.m/W]	0.9
Consider Non-Isothermal Earth Surface		No

Results Summary

Cable No.	Cable ID	Circuit No.	Feeder ID	Cable Phase	Cable Frequency	Daily Load Factor	X coordinate [m]	Y coordinate [m]	Conductor temperature [°C]	Ampacity [A]
1	1C-1000-AL-1_1	1		A	60.0	1.0	-1.83	0.93	77.3	475.0
2	1C-1000-AL-1_1	1		B	60.0	1.0	-1.77	0.93	79.2	475.0
3	1C-1000-AL-1_1	1		C	60.0	1.0	-1.8	0.88	76.4	475.0
4	1C-1000-AL-1_1	2		A	60.0	1.0	-1.03	0.93	79.1	422.0
5	1C-1000-AL-1_1	2		B	60.0	1.0	-0.97	0.93	79.5	422.0
6	1C-1000-AL-1_1	2		C	60.0	1.0	-1.0	0.88	77.1	422.0
7	1C-1000-AL-1_1	3		A	60.0	1.0	-0.23	0.93	83.2	422.0
8	1C-1000-AL-1_1	3		B	60.0	1.0	-0.17	0.93	83.3	422.0
9	1C-1000-AL-1_1	3		C	60.0	1.0	-0.2	0.88	80.9	422.0
10	1C-1000-AL-1_1	4		A	60.0	1.0	0.57	0.93	84.0	422.0
11	1C-1000-AL-1_1	4		B	60.0	1.0	0.63	0.93	83.9	422.0
12	1C-1000-AL-1_1	4		C	60.0	1.0	0.6	0.88	81.6	422.0
13	1C-1000-AL-1_1	5		A	60.0	1.0	1.37	0.93	82.5	422.0
14	1C-1000-AL-1_1	5		B	60.0	1.0	1.43	0.93	82.4	422.0
15	1C-1000-AL-1_1	5		C	60.0	1.0	1.4	0.88	80.2	422.0
16	1C-1000-AL-1_1	6		A	60.0	1.0	2.07	0.93	83.5	475.0
17	1C-1000-AL-1_1	6		B	60.0	1.0	2.13	0.93	81.4	475.0
18	1C-1000-AL-1_1	6		C	60.0	1.0	2.1	0.88	80.5	475.0