Magnetic Field Calculations for Middletown-Norwalk 345 kV XLPE Transmission Cables
September 27, 2004

Introduction

Power Delivery Consultants (PDC) performed magnetic field calculations for the Singer-Norwalk and E. Devon-Singer 345 kV underground transmission lines for three and eight feet of duct bank cover as shown in Figures 1 and 4 respectively. Power Delivery Consultants, Inc (PDC) estimates that the center-to-center conduit spacing for the 345 kV transmission cables would have to be increased from 11.9" to 17" when the duct bank cover is increased from 3' to 8' to maintain the same ampacity rating. The line loadings were assumed to be the same as for the HPFF lines previously described for the Singer to Norwalk and East Devon-Singer underground lines under a 15GW case.

Magnetic field values were not calculated with steel plate shielding due to time constraints. However, laboratory tests and calculations for similar cable installation conditions indicate that the magnetic field values directly above the duct bank in Figure 1 covered by a 3/8" steel plate would be reduced to approximately one-half of the EMF values with no shielding. This 2 to 1 reduction in the maximum magnetic field (at one meter above ground) would be achieved by placing a 39" wide, 3/8" thick, 1010 carbon steel plate on top of the cable duct bank as shown in Figure 7. Reduction of the above ground magnetic field values would be limited to a width of approximately 20 to 30 feet centered on the cable trench.

PDC is in the process of investigating other methods for mitigation of magnetic fields above the Middletown-Norwalk 345 kV XLPE transmission cables.

Installation Conditions

Six, 3000 kcmil, compact segmental, copper conductor cables (two cables per phase) would be installed in a concrete encased duct bank with the dimensions shown in Figure 1.

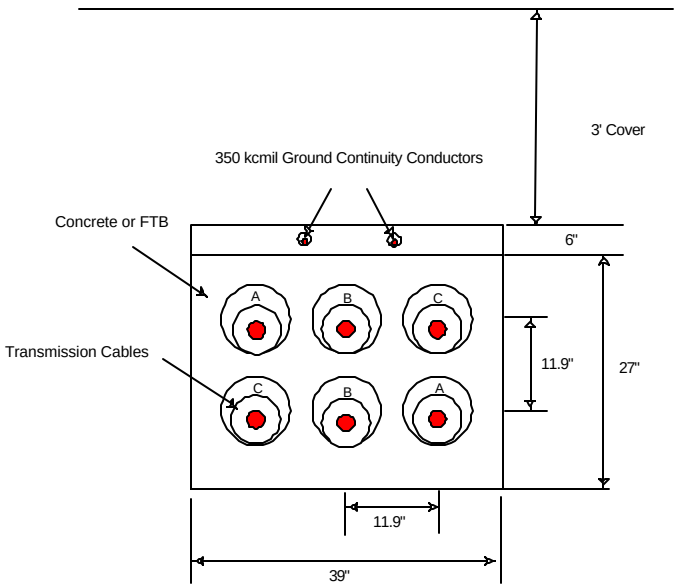

Figure 1. Concrete Encased Duct Bank Cross Section, 3' Duct Bank Cover

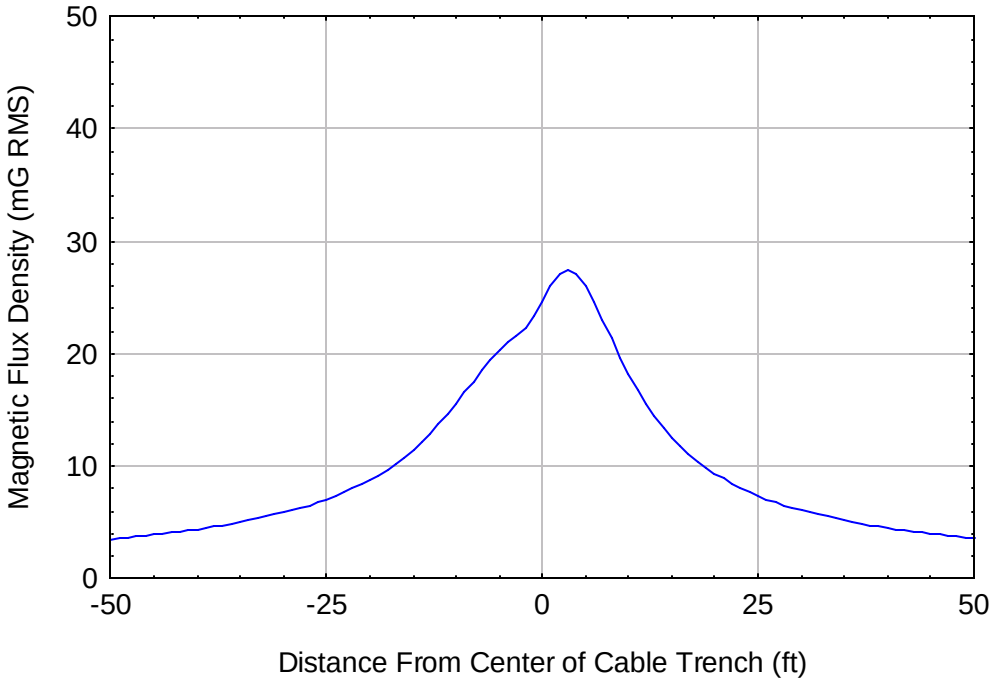

Figure 2. Singer-Norwalk Magnetic Field Values from 345-kV XPLE underground cables, 3' Cover, 15 GW System Load
Magnetic Field Values (mG) at one meter above ground level

Table 1 contains the RMS values of the magnetic flux density at one meter above ground as a function of distance from the center of the trench. The second and third columns are the major axis and resultant values of the magnetic flux density in mG.

Table 1- Singer-Norwalk Magnetic Field Values, 3' Cover, 15 GW System Load

Distance (ft)	Major Axis (mG)	Resultant (mG)
-50.00	3.51	3.51
-49.00	3.58	3.59
-48.00	3.66	3.66
-47.00	3.74	3.74
-46.00	3.82	3.82
-45.00	3.90	3.91
-44.00	3.99	4.00
-43.00	4.09	4.09
-42.00	4.18	4.19
-41.00	4.29	4.29
-40.00	4.39	4.40
-39.00	4.51	4.51
-38.00	4.63	4.63
-37.00	4.75	4.76
-36.00	4.88	4.89
-35.00	5.02	5.03
-34.00	5.17	5.18
-33.00	5.33	5.34
-32.00	5.49	5.51
-31.00	5.67	5.69
-30.00	5.86	5.88
-29.00	6.06	6.08
-28.00	6.27	6.30
-27.00	6.50	6.53
-26.00	6.75	6.78
-25.00	7.01	7.05
-24.00	7.29	7.34
-23.00	7.60	7.65
-22.00	7.93	7.99
-21.00	8.29	8.36
-20.00	8.68	8.76
-19.00	9.10	9.20
-18.00	9.57	9.68
-17.00	10.07	10.20
-16.00	10.62	10.78
-15.00	11.23	11.41
-14.00	11.89	12.10
-13.00	12.62	12.85
-12.00	13.42	13.67
-11.00	14.29	14.56
-10.00	15.24	15.51
-9.00	16.26	16.51
-8.00	17.33	17.54
-7.00	18.42	18.55
-6.00	19.46	19.50
-5.00	20.33	20.33
-4.00	20.90	21.03
-3.00	21.10	21.65
-2.00	21.13	22.35
-1.00	21.71	23.34
0.00	23.38	24.66
1.00	25.44	26.07

2.00	26.95	27.12
3.00	27.49	27.49
4.00	27.07	27.10
5.00	25.93	26.09
6.00	24.37	24.66
7.00	22.65	23.02
8.00	20.92	21.34
9.00	19.28	19.72
10.00	17.78	18.20
11.00	16.43	16.82
12.00	15.22	15.57
13.00	14.15	14.45
14.00	13.19	13.46
15.00	12.34	12.57
16.00	11.58	11.77
17.00	10.90	11.06
18.00	10.29	10.43
19.00	9.74	9.85
20.00	9.24	9.34
21.00	8.78	8.87
22.00	8.37	8.44
23.00	7.99	8.05
24.00	7.65	7.70
25.00	7.33	7.37
26.00	7.04	7.07
27.00	6.76	6.80
28.00	6.51	6.54
29.00	6.28	6.30
30.00	6.06	6.08
31.00	5.86	5.88
32.00	5.67	5.68
33.00	5.49	5.50
34.00	5.32	5.33
35.00	5.16	5.17
36.00	5.01	5.02
37.00	4.87	4.88
38.00	4.74	4.75
39.00	4.61	4.62
40.00	4.49	4.50
41.00	4.38	4.39
42.00	4.27	4.28
43.00	4.17	4.18
44.00	4.07	4.08
45.00	3.98	3.98
46.00	3.89	3.89
47.00	3.81	3.81
48.00	3.72	3.73
49.00	3.65	3.65
50.00	3.57	3.57
51.00	3.50	3.50

Results of the magnetic field calculations for the 3' depth of cover are shown in Figure 3 for E. Devon-Singer, 15 GW system load conditions. The magnitude of the currents flowing in each of the six cables would be 285 A.

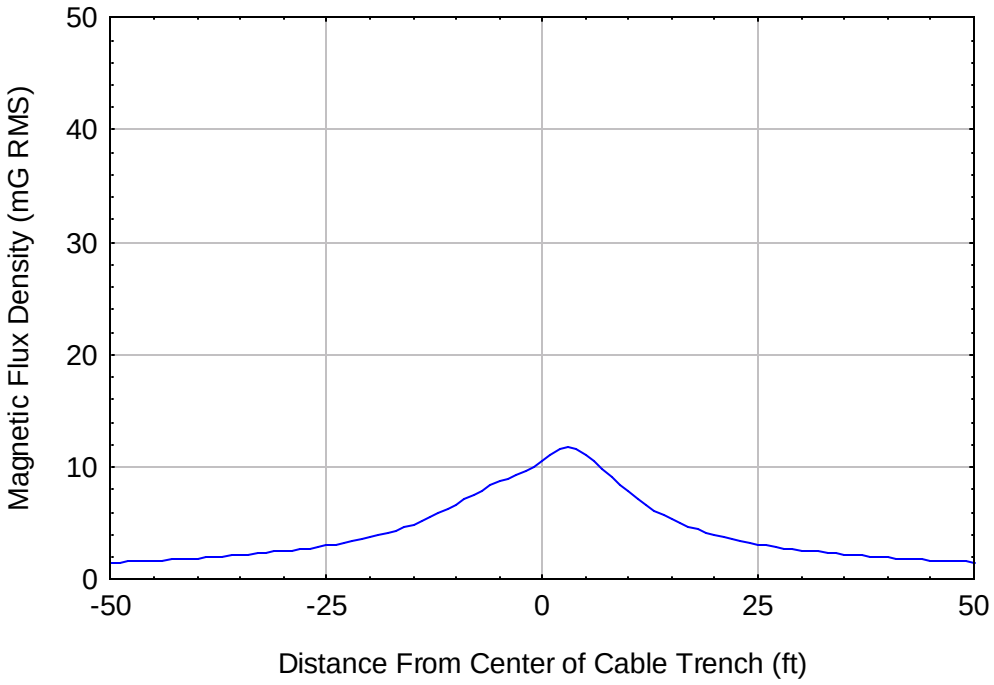

Figure 3. E. Devon-Singer Magnetic Field Values for 345-kV XPLE underground cables, 3' Cover, 15 GW System Load
Magnetic Field Values (mG) at one meter above ground level

Table 2 contains the RMS values of the magnetic flux density at one meter above ground as a function distance from the center of the trench. The second and third columns are the major axis and resultant values of the magnetic flux density in mG.

Table 2- E. Devon-Singer Magnetic Field Values for XLPE underground cables, 3' Cover, 15 GW System Load

Distance (ft)	Major Axis (mG)	Resultant (mG)
-50.00	1.51	1.51
-49.00	1.54	1.54
-48.00	1.57	1.57
-47.00	1.60	1.60
-46.00	1.64	1.64
-45.00	1.67	1.67
-44.00	1.71	1.71
-43.00	1.75	1.75
-42.00	1.79	1.80
-41.00	1.84	1.84
-40.00	1.88	1.89
-39.00	1.93	1.93
-38.00	1.98	1.99
-37.00	2.04	2.04
-36.00	2.09	2.10
-35.00	2.15	2.16
-34.00	2.22	2.22
-33.00	2.28	2.29
-32.00	2.35	2.36
-31.00	2.43	2.44
-30.00	2.51	2.52
-29.00	2.60	2.61
-28.00	2.69	2.70
-27.00	2.79	2.80
-26.00	2.89	2.91
-25.00	3.00	3.02
-24.00	3.13	3.14
-23.00	3.26	3.28
-22.00	3.40	3.42
-21.00	3.55	3.58
-20.00	3.72	3.76
-19.00	3.90	3.94
-18.00	4.10	4.15
-17.00	4.32	4.37
-16.00	4.55	4.62
-15.00	4.81	4.89
-14.00	5.10	5.18
-13.00	5.41	5.51
-12.00	5.75	5.86
-11.00	6.12	6.24
-10.00	6.53	6.65
-9.00	6.97	7.08
-8.00	7.43	7.52
-7.00	7.89	7.95
-6.00	8.34	8.36
-5.00	8.71	8.71
-4.00	8.96	9.01
-3.00	9.04	9.28
-2.00	9.06	9.58
-1.00	9.30	10.00

0.00	10.02	10.57
1.00	10.90	11.17
2.00	11.55	11.62
3.00	11.78	11.78
4.00	11.60	11.62
5.00	11.11	11.18
6.00	10.45	10.57
7.00	9.71	9.87
8.00	8.96	9.15
9.00	8.26	8.45
10.00	7.62	7.80
11.00	7.04	7.21
12.00	6.52	6.67
13.00	6.06	6.19
14.00	5.65	5.77
15.00	5.29	5.39
16.00	4.96	5.05
17.00	4.67	4.74
18.00	4.41	4.47
19.00	4.17	4.22
20.00	3.96	4.00
21.00	3.76	3.80
22.00	3.59	3.62
23.00	3.43	3.45
24.00	3.28	3.30
25.00	3.14	3.16
26.00	3.02	3.03
27.00	2.90	2.91
28.00	2.79	2.80
29.00	2.69	2.70
30.00	2.60	2.61
31.00	2.51	2.52
32.00	2.43	2.44
33.00	2.35	2.36
34.00	2.28	2.29
35.00	2.21	2.22
36.00	2.15	2.15
37.00	2.09	2.09
38.00	2.03	2.03
39.00	1.98	1.98
40.00	1.93	1.93
41.00	1.88	1.88
42.00	1.83	1.83
43.00	1.79	1.79
44.00	1.75	1.75
45.00	1.71	1.71
46.00	1.67	1.67
47.00	1.63	1.63
48.00	1.60	1.60
49.00	1.56	1.56
50.00	1.53	1.53
51.00	1.50	1.50

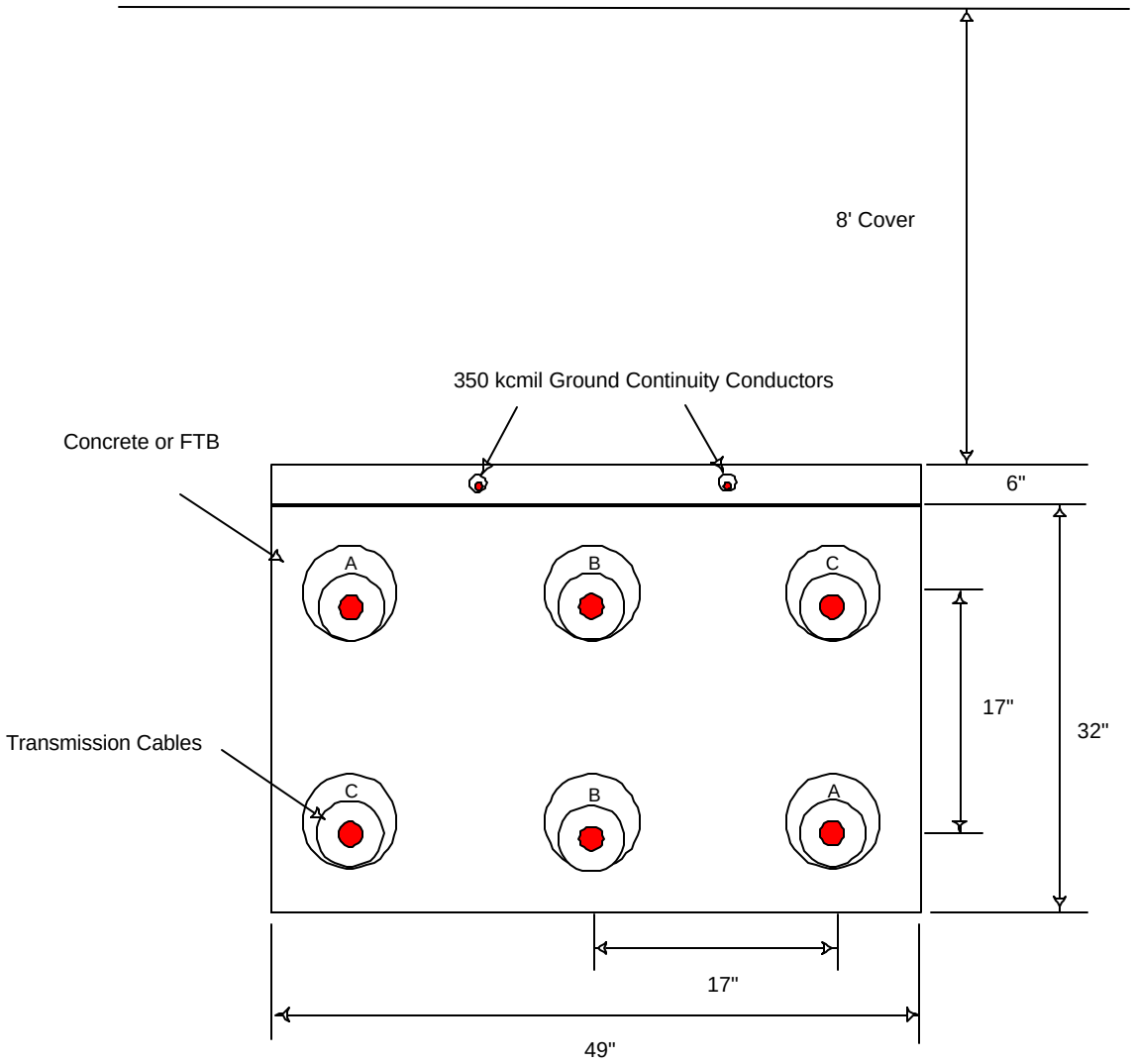

Figure 4. Concrete Encased Duct Bank Cross Section, 8' Duct Bank Cover

Results of the magnetic field calculations for the 8' depth of cover are shown in Figure 5 and for Singer-Norwalk, 15 GW system load conditions. The magnitudes of the currents in each of the cable would be 666 A.

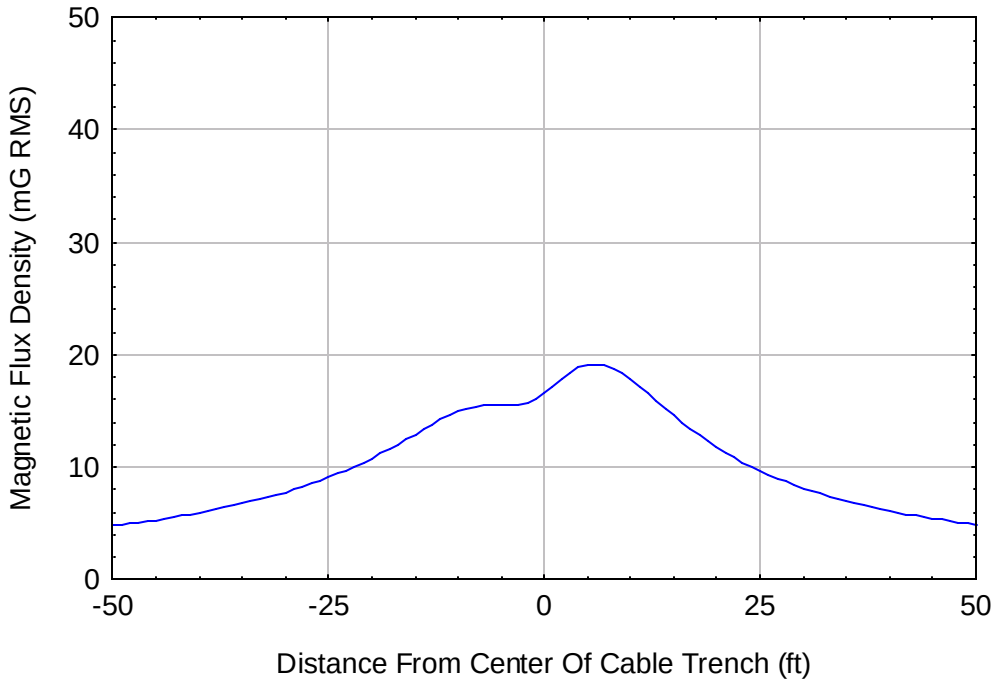

Figure 5. Singer-Norwalk Magnetic Field Values for XLPE underground cables, 8' Cover, 15 GW System Load
Magnetic Field Values (mG) at one meter above ground level

Table 3 contains the RMS values of the magnetic flux density at one meter above ground as a function distance from the center of the trench. The second and third columns are the major axis and resultant values of the magnetic flux density in mG.

A comparison of the magnetic field values for 3' and 8' of duct bank cover (Figures 2 and 5) indicate that the maximum magnetic field value would be decreased. However, the magnetic field values for distances greater than 11' from the center of the cable trench would be higher for the 8' duct bank depth due to the greater spacing between conduits (i.e. 11.9" vs. 17").

Table 3- Singer-Norwalk Magnetic Field Values for XLPE underground cables, 8' Cover, 15 GW System Load

Distance (ft)	Major Axis (mG)	Resultant (mG)
-50.00	4.78	4.79
-49.00	4.87	4.88
-48.00	4.97	4.98
-47.00	5.08	5.08
-46.00	5.18	5.19
-45.00	5.29	5.30
-44.00	5.41	5.42
-43.00	5.53	5.54
-42.00	5.66	5.67
-41.00	5.79	5.80
-40.00	5.92	5.94
-39.00	6.07	6.08
-38.00	6.22	6.24
-37.00	6.38	6.39
-36.00	6.54	6.56
-35.00	6.72	6.74
-34.00	6.90	6.92
-33.00	7.09	7.11
-32.00	7.29	7.32
-31.00	7.50	7.53
-30.00	7.72	7.76
-29.00	7.96	8.00
-28.00	8.20	8.25
-27.00	8.46	8.51
-26.00	8.74	8.79
-25.00	9.03	9.09
-24.00	9.33	9.40
-23.00	9.65	9.72
-22.00	9.99	10.07
-21.00	10.35	10.43
-20.00	10.72	10.81
-19.00	11.11	11.20
-18.00	11.52	11.62
-17.00	11.94	12.04
-16.00	12.38	12.48
-15.00	12.83	12.92
-14.00	13.28	13.36
-13.00	13.72	13.79
-12.00	14.16	14.21
-11.00	14.56	14.59
-10.00	14.92	14.93
-9.00	15.21	15.21
-8.00	15.39	15.41
-7.00	15.43	15.53
-6.00	15.30	15.58
-5.00	14.95	15.58
-4.00	14.38	15.56
-3.00	13.60	15.60
-2.00	12.77	15.75
-1.00	12.74	16.07

0.00	14.02	16.56
1.00	15.53	17.17
2.00	16.86	17.82
3.00	17.92	18.41
4.00	18.65	18.86
5.00	19.06	19.12
6.00	19.17	19.18
7.00	19.04	19.04
8.00	18.71	18.74
9.00	18.24	18.30
10.00	17.67	17.77
11.00	17.04	17.17
12.00	16.38	16.53
13.00	15.72	15.88
14.00	15.06	15.23
15.00	14.42	14.59
16.00	13.80	13.97
17.00	13.22	13.37
18.00	12.66	12.81
19.00	12.14	12.27
20.00	11.64	11.77
21.00	11.18	11.29
22.00	10.74	10.85
23.00	10.33	10.43
24.00	9.95	10.04
25.00	9.59	9.67
26.00	9.25	9.32
27.00	8.93	9.00
28.00	8.64	8.69
29.00	8.35	8.40
30.00	8.09	8.13
31.00	7.84	7.88
32.00	7.60	7.64
33.00	7.38	7.41
34.00	7.17	7.20
35.00	6.97	6.99
36.00	6.78	6.80
37.00	6.60	6.62
38.00	6.42	6.44
39.00	6.26	6.28
40.00	6.11	6.12
41.00	5.96	5.97
42.00	5.82	5.83
43.00	5.68	5.69
44.00	5.55	5.56
45.00	5.43	5.44
46.00	5.31	5.32
47.00	5.20	5.21
48.00	5.09	5.10
49.00	4.98	4.99
50.00	4.88	4.89
51.00	4.79	4.79

Results of the magnetic field calculations for the 8’ depth of cover are shown in Figure 6 for E. Devon-Singer, 15 GW system load conditions. The magnitude of the currents flowing in each of the six cables would be 285 A.

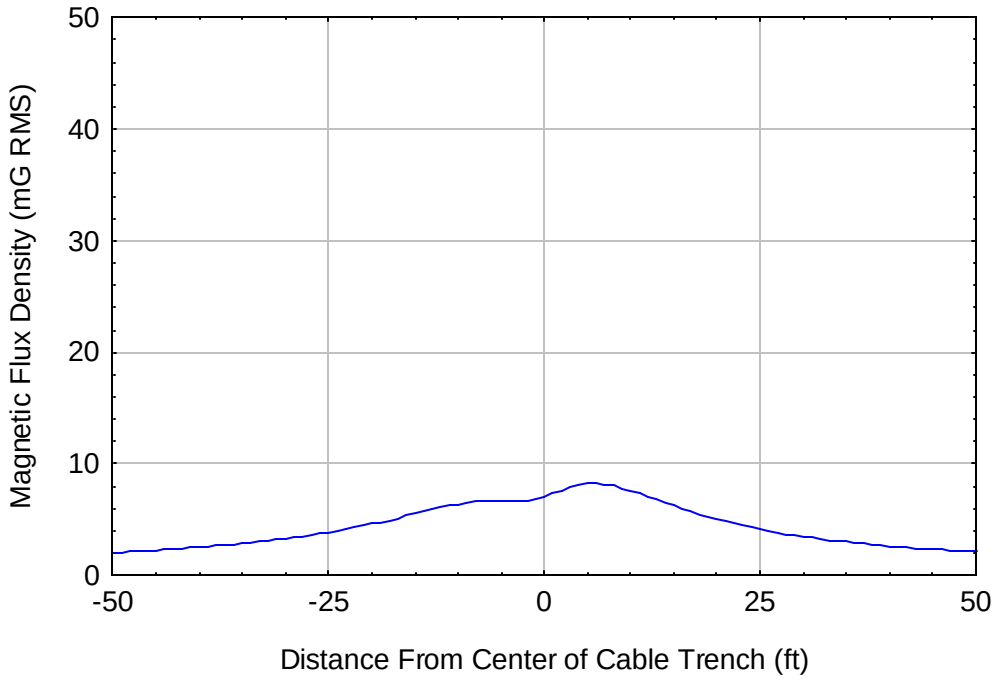

Figure 6. E. Devon-Singer Magnetic Field Values for XLPE underground cables, 8’ Cover, 15 GW System Load
Magnetic Field Values (mG) at one meter above ground level

Table 4 contains the RMS values of the magnetic flux density at one meter above ground as a function distance from the center of the trench. The second and third columns are the major axis and resultant values of the magnetic flux density in mG.

Table 4- E. Devon-Singer Magnetic Field Values for XLPE underground cables, 8' Cover, 15 GW System Load

Distance (ft)	Major Axis (mG)	Resultant (mG)
-50.00	2.05	2.05
-49.00	2.09	2.09
-48.00	2.13	2.13
-47.00	2.18	2.18
-46.00	2.22	2.22
-45.00	2.27	2.27
-44.00	2.32	2.32
-43.00	2.37	2.37
-42.00	2.42	2.43
-41.00	2.48	2.49
-40.00	2.54	2.54
-39.00	2.60	2.61
-38.00	2.67	2.67
-37.00	2.73	2.74
-36.00	2.80	2.81
-35.00	2.88	2.89
-34.00	2.96	2.97
-33.00	3.04	3.05
-32.00	3.12	3.14
-31.00	3.21	3.23
-30.00	3.31	3.33
-29.00	3.41	3.43
-28.00	3.52	3.53
-27.00	3.63	3.65
-26.00	3.75	3.77
-25.00	3.87	3.89
-24.00	4.00	4.03
-23.00	4.14	4.17
-22.00	4.28	4.31
-21.00	4.43	4.47
-20.00	4.59	4.63
-19.00	4.76	4.80
-18.00	4.94	4.98
-17.00	5.12	5.16
-16.00	5.31	5.35
-15.00	5.50	5.54
-14.00	5.69	5.73
-13.00	5.88	5.91
-12.00	6.07	6.09
-11.00	6.24	6.25
-10.00	6.39	6.40
-9.00	6.52	6.52
-8.00	6.59	6.60
-7.00	6.61	6.66
-6.00	6.56	6.68
-5.00	6.41	6.68
-4.00	6.16	6.67
-3.00	5.83	6.68
-2.00	5.47	6.75

-1.00	5.46	6.89
0.00	6.01	7.10
1.00	6.65	7.36
2.00	7.23	7.64
3.00	7.68	7.89
4.00	7.99	8.08
5.00	8.17	8.20
6.00	8.22	8.22
7.00	8.16	8.16
8.00	8.02	8.03
9.00	7.82	7.84
10.00	7.57	7.61
11.00	7.30	7.36
12.00	7.02	7.08
13.00	6.74	6.80
14.00	6.45	6.53
15.00	6.18	6.25
16.00	5.92	5.99
17.00	5.66	5.73
18.00	5.43	5.49
19.00	5.20	5.26
20.00	4.99	5.04
21.00	4.79	4.84
22.00	4.60	4.65
23.00	4.43	4.47
24.00	4.26	4.30
25.00	4.11	4.14
26.00	3.97	3.99
27.00	3.83	3.86
28.00	3.70	3.72
29.00	3.58	3.60
30.00	3.47	3.49
31.00	3.36	3.38
32.00	3.26	3.27
33.00	3.16	3.18
34.00	3.07	3.08
35.00	2.99	3.00
36.00	2.90	2.91
37.00	2.83	2.84
38.00	2.75	2.76
39.00	2.68	2.69
40.00	2.62	2.62
41.00	2.55	2.56
42.00	2.49	2.50
43.00	2.43	2.44
44.00	2.38	2.38
45.00	2.33	2.33
46.00	2.28	2.28
47.00	2.23	2.23
48.00	2.18	2.18
49.00	2.14	2.14
50.00	2.09	2.10
51.00	2.05	2.05

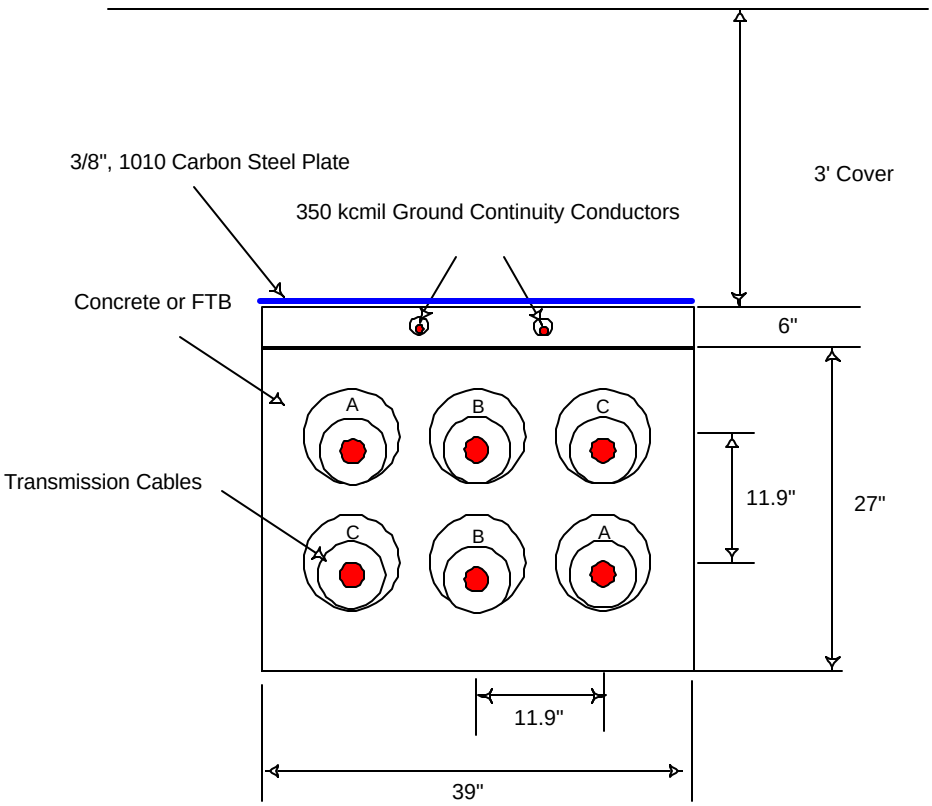

Figure 7. Duct bank cross section with 3/8" steel plate for magnetic field shielding