ELECTRIC AND MAGNETIC FIELDS REPORT

Project # 169201

The Champlain Hudson Power Express Project

prepared for

Champlain Hudson Power Express, Inc.
Pieter Schuyler Building
600 Broadway
Albany, New York 12207-2283

prepared by

TRC
249 Western Avenue
Augusta, ME 04330
(207) 621-7000

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1. INTRODUCTION

Champlain Hudson Power Express, Inc. (CHPEI) proposes to connect renewable sources of power generation in central and eastern Canada and upstate New York to load centers in and around the New York City and southwestern Connecticut regions. The project will include four (4) underwater and underground high-voltage direct current (HVDC) transmission cables routed along existing waterways from HVDC converter stations in Canada to HVDC converter stations in Yonkers, New York and Bridgeport, Connecticut. The four cables comprise two HVDC bipoles. Each bipole will utilize a second cable as the metallic return. One bipole pair will terminate in New York City. The other bipole pair will terminate in Bridgeport, Connecticut.

TRC Engineers (TRC) have been engaged by CHPEI to investigate the magnetic and electric fields produced by the HVDC cables. TRC will quantify the future electric and magnetic field levels resulting from the construction of the project. The report describes all field calculations performed and compares the results with transmission line standards/guidelines for magnetic and electric fields in New York State.

2. OVERVIEW

2.1. Electric Fields

Voltage on any wire, whether an overhead phase conductor or lamp cords, produces an electric field in the area surrounding the wire. Electric fields are invisible lines of force that repel or attract electrical charges. As with a magnet, if the charges are the same (i.e., either both positive and both negative), the charges repel each other. If the charges are different (i.e., one negative and one positive), there would be an attractive force between them.

Electric fields are proportional to the operating voltage of the transmission line. The line voltage is controlled within a small range (usually ± 10 percent) and, hence, little variation is expected in the electric field levels.

2.2. Magnetic Fields

Any object with an electric charge has a voltage (potential) at its surface and can create an electric field. When electrical charges move together (an electric current) they create a magnetic field, which can exert force on other electric currents. All currents create magnetic fields. Magnetic fields occur throughout nature and are one of the basic forces of nature. The strength of the magnetic field depends on the current (higher currents create higher magnetic fields), the configuration/size of the source, spacing between conductors, and distance (magnetic fields grow weaker as the distance from the source increases).

Magnetic fields can be static, i.e., unchanging in direction (caused by "direct current", "DC") or changing in direction (caused by alternating current", "AC"). Some electrical devices operate on a DC system while others operate on an AC system. The magnetic field from AC sources (such as the electrical transmission lines) differ from DC fields (like the Earth) because the field is due to alternating currents ("AC") and changes direction at a rate of 60 cycles per second or 60 Hertz (Hz) in the United States and certain other countries.

The characteristics of magnetic fields can differ depending on the field source. A magnetic field near an appliance decreases rapidly with distance away from the device. The magnetic field also decreases with distance away from line sources, such as power lines, but not as rapidly as it does with appliances. Electric transmission line magnetic fields attenuate at a rate that is inversely proportional to the distance squared, whereas magnetic fields from appliances attenuate at a rate proportional to the distance cubed. For electric transmission lines, magnetic and electric field levels are highest next to the transmission lines (typically near the center of the electric transmission line right-of-way) and decrease as the distance from the transmission right-of-way or corridor increases.

Measured magnetic field strengths can be compared to magnetic fields typically associated with existing transmission line rights-of-way and with those typically associated with various electrical devices and phenomena. Typical magnetic field levels produced at distances of 1 ft. and 2 ft. from some common household appliances are shown in Table 1, on the following page.

Electric and magnetic guidelines have been established by various organizations, and comparison to these values helps assess the potential for human health impacts from transmission line fields. Table 2, on the following page, summarizes the levels of magnetic fields associated with various devices or phenomena along with several guidelines established by various organizations.

Table 1 - Magnetic Field Levels of Various Household Appliances

Appliance	Magnetic Field at 1 ft.	Magnetic Field at 2 ft
Hair Dryer	Bg - 70	Bg -10
Window A/C	Bg - 20	Bg - 6
Color TV	Bg - 20	Bg - 8
Dishwasher	6 - 30	2 - 7
Refrigerator	Bg - 20	Bg - 10
Can Opener	40 - 300	3 - 30
Microwave Oven	1 - 200	1 - 30
Washing Machine	1 - 30	Bg – 6
Power Drill	20 - 40	3 - 6
	mG	**mG**

Source EMFRAPID Program June 2002. Bg = Measurement indistinguishable from background levels.

Table 2 - Magnetic Field Levels of Various Devices, Phenomena and Standards

Device, Phenomenon or Standard	Magnetic Field
Magnetic Resonance Imaging (MRI) scan	20,000,000 (DC)
Permanent magnet	100,000 (DC)
Earth's magnetic field (over the United States)	470 to 590 (DC)
IEEE standard for the general public (2002)	9,040
ICNIRP occupational guideline (1998)	4,167
ACGIH guideline for occupational exposures (2002)	10,000
ACGIH guideline for individuals with pacemakers	1,000
ICNIRP general public guideline (1998)	833
New York Edge of ROW interim standard (1990)	200
Hair dryers and electric blankets	100 to 500
Typical household appliance	40 to 80
Typical in-home fields away from appliances	0.5 to 2.5
	mG

Notes: (DC) These magnetic fields are steady fields (not time-varying) as opposed to the other fields listed in Table 2, which are low-frequency (60 Hz), time-varying fields.

3. ELECTRIC AND MAGNETIC FIELD STANDARDS

3.1. General

There are no Federal standards limiting residential or occupational exposure to DC or low frequency (60 Hz) magnetic or electric fields.

3.2. New York Public Service Commission Electric Field Standards

The applicable electric field strength standards established by the PSC are set forth in Opinion No. 78-13 (issued June 19, 1978). The opinion established an electric field strength interim standard of 1.6 kilovolts per meter (kV/m) for electric transmission lines, at the edge of the right-of-way, one meter above ground level, with the line at the rated voltage.

3.3. New York Public Service Commission Magnetic Field Standards

The magnetic field standards established by the PSC are set forth in the PSC's Interim Policy Statement on Magnetic Fields, issued September 11, 1990. The interim policy established a magnetic field strength interim standard of 200 milligauss (mG), measured at one meter above grade, at the edge of the right-of-way, at the point of lowest conductor sag. The measurement is based on the expected circuit currents being equal to the winter-normal conductor rating.

4. DISCUSSION

4.1. General

The portion of the new underground and underwater HVDC transmission facility located in the United States is approximately 385 miles long. Two cables (one bipole) will extend approximately 319 miles from the U.S./Canadian border to a converter station in Yonkers, New York. The remaining two cables (the other bipole) will be extended 66 miles further to a converter station in Bridgeport, Connecticut

TRC has selected five (5) typical locations along the route of the project where the configuration changes. These calculation locations which will be analyzed are:

1. On-land burial
2. In Lake Champlain
3. In the Champlain Canal
4. Adjacent to the Canadian Pacific (CP) Railroad
5. In the Hudson River south of Albany

Magnetic field levels at each of the five (5) locations were calculated. The materials and design criteria chosen and described in Section 4.2, below, represent the standard, preferred construction arrangement throughout this project. There may be locations that will require alternate design criteria (conductor size, cable spacing, etc) due to unique requirements of those sites.

Electric field levels will not be calculated. The new HVDC transmission cables will be buried in the ground or installed in a trench at the bottom of the waterways. When installed in this manner, electric field levels are reduced to inconsequential levels because of earth cover over the buried cables in the underground system.

4.2. Magnetic Field Calculations

The magnetic field levels in this report were all calculated using the C3CORONA, Version 3, the corona and field effects software program developed by the Bonneville Power Administration and the U.S. Department of Energy. The calculations did not consider any energized sources along the route other than the HVDC cable system which is the subject of this report.

A computer simulation was developed to calculate the magnetic field levels at each of the five (5) typical locations. To facilitate the field calculations, C3CORONA calculates field levels along a profile which is oriented to be at right angles to the proposed cable system. The reader of the report is always looking south with Canada at his or her back. For each location, the levels were calculated at a height of one (1) meter above ground (1 meter above the surface of the water in waterways) and at increments of five (5) feet from a point fifty feet (50 ft) easterly (left) of the centerline of the cable configuration to a point fifty feet (50 ft) westerly (right) of the centerline for a total profile length of one hundred feet (100 ft). The magnetic field levels in this report are expressed in units of milligauss (mG).

The four (4) cables in each of the locations are arranged in a flat, horizontal configuration. The horizontal separation between cables varies. The vertical location of the cable configuration is a function of the depth of the burial trench for the underground cables, and, a function of the depth of the water PLUS the depth of the burial trench for the underwater cables. Table 3, below, describes these factors for each location.

Table 3 - Factors Affecting Physical Location of Cable System

Calculation Location	Depth of Water	Depth of Trench	Horizontal Separation between the Four Cables
On-land Burial	--	3 feet	3 feet – 12 feet – 3 feet
Lake Champlain	400 feet	3 feet	11.6 feet – 11.6 feet – 11.6 feet
Champlain Canal	12 feet	3 feet	11.6 feet – 11.6 feet – 11.6 feet
CP Railroad	--	3 feet	3 feet – 26 feet – 3 feet
Hudson River	32 feet	15 feet	11.6 feet – 11.6 feet – 11.6 feet

Each transmission circuit (bipole) will use two single conductor cables. Each cable will be a 300 kilovolt insulated cable having a 1400 mm^2 copper conductor approximately 1.85 inches in diameter. The overall diameter of the insulated cable is approximately 4.15 inches. The field calculations will be carried out assuming the cable current to be 1837A.

The right-of-way width for the on-land, Lake Champlain, Champlain Canal, and Hudson River segments is assumed to be seventy-five feet (75 ft). The right-of-way width for the Canadian Pacific Railroad segment is assumed to be sixty-six feet (66 ft).

All electrical or physical input parameters used in TRC's calculations, i.e., the physical location and configuration of the underground HVDC cables, the right-of-way width, the cable types and sizes, the operating voltages, circuit load currents and the cable voltage polarities were either supplied by the client to TRC or were developed by TRC Staff. The horizontal spacing of the HVDC cables in underwater locations (Lake Champlain, the Champlain Canal and the Hudson River) used in the field calculations is based on the cable manufacturer's minimum recommended cable spacing. The design drawings provided in Exhibit 5 – Design Drawings of the CHPEI Article VII Application indicate a slightly greater horizontal spacing. These design drawings describe the preferred design for this project.

5. RESULTS

The calculated magnetic field levels at each of the five (5) locations are summarized in Table 4, on the following page. Levels are shown at five (5) foot increments along the one hundred (100) foot profile centered on the cable configuration from a point negative fifty feet (-50 ft) east of the cables to a point positive fifty feet (+50 ft) west of the cables. In addition, Table 4 also includes levels calculated at the edges of the right-of-way for each location.

Table 4 entries describing magnetic field levels at the edges of right-of-way or outside (beyond the edges of the right-of-way) are highlighted in yellow.

6. ANALYSIS

The transmission line standards/guidelines for magnetic and electric fields in New York can be described as follows:

- The maximum magnetic field at the edge of a right-of-way for a major transmission line is 200 mG. as set forth in the Statement of Interim Policy on Magnetic Fields of Major Transmission Facilities, issued and effective September 11, 1990. (Reference 4)

- The maximum electric field at the edge of a right-of-way for a major transmission line is 1.6kV/m as set forth in PSC Opinion 78-13, dated June 19, 1978. (Reference 5)

An examination of the results of the calculations summarized in Table 4 demonstrates that this project, if configured and constructed as described in this report, would satisfy the requirements described in the Statement of Interim Policy on Magnetic Fields of Major Transmission Facilities. This is demonstrated by the fact that all field levels in Table 4 in red (edge of right-of-way) are less than 200 mG. It should also be noted that all field levels calculated are less than the Earth's magnetic field over North America which is in the range of 470 to 590 (DC) mG (see Table 2 on Page 3)

The magnetic field levels at the edges of the right-of-way only for each calculation location were extracted from Table 4 and are summarized in Table 5, on the following page.

Table 4 - Calculated Magnetic Field Levels

HORIZONTAL COORDINATE	CONFIGURATION / LOCATION				
	On-Land	Lake Champlain	Champlain Canal	Canadian Pacific R.R.	Hudson River
-50	30.4	1.7	111.1	36.4	55.5
-45	38.0	1.7	135.3	47.3	60.7
-40	48.8	1.7	167.2	64.3	66.0
-37.5	56.9	1.7	188.0		68.7
-35	65.0	1.7	208.7	92.8	71.4
-33				114.1	
-30	91.1	1.7	261.0	146.1	76.6
-25	137.0	1.7	320.4	259.9	81.5
-20	227.3	1.7	372.8	523.0	85.7
-15	425.3	1.7	394.6	829.6	89.1
-10	755.0	1.7	369.7	556.2	91.6
-5	583.3	1.7	312.3	273.4	93.1
0	115.9	1.7	278.4	198.0	93.6
+5	583.3	1.7	312.3	273.4	93.1
+10	755.0	1.7	369.7	556.2	91.6
+15	425.3	1.7	394.6	829.6	89.1
+20	227.3	1.7	372.8	523.0	85.7
+25	137.0	1.7	320.4	259.9	81.5
+30	91.1	1.7	261.0	146.1	76.6
+33				114.1	
+35	65.0	1.7	208.7	92.8	71.4
+37.5	56.9	1.7	188.0		68.7
+40	48.8	1.7	167.2	64.3	66.0
+45	38.0	1.7	135.3	47.3	60.7
+50	30.4	1.7	111.1	36.4	55.5
feet	milligauss	milligauss	milligauss	milligauss	milligauss

Table 5 - Magnetic Field Level at Edges of Right-of-Way for each Calculation Location

Calculation Location	ROW Width	Location of Edges of Right-of-Way	Calculated Magnetic Field Level
On-land Burial	75 feet	±37.5 feet	56.9 mG.
Lake Champlain	75 feet	±37.5 feet	1.7 mG.
Champlain Canal	75 feet	±37.5 feet	188 mG.
CP Railroad	66 feet	±33 feet	114.1 mG
Hudson River	75 feet	±37.5 feet	68.7 mG

Finally, since the HVDC cables are buried in the ground or installed in a trench at the bottom of the waterways, electric field levels are reduced to inconsequential levels and therefore were not presented in this study.

7. CONCLUSION

An examination of Table 5 demonstrates that the all magnetic field levels at the edges of the right-of-way at the five (5) typical calculation locations meet the requirements of New York State.

8. REFERENCES

1. – *Champlain Hudson Power Express HVDC Transmission Project, Presidential Permit Application*, TDI, January 2010.

2. – *Champlain Hudson Power Express*, *Cable System Study Report*, Nexans Norway As, January 18, 2010.

3. – *Statement of Interim Policy on Magnetic Fields of Major Transmission Facilities*, issued and effective September 11, 1990.

4. – *PSC Opinion 78-13*, dated June 19, 1978.