7. ENGINEERING AND OPERATIONAL DESIGN OF THE PROPOSED HVTL AND SUBSTATIONS

7.1 Transmission Line Design Voltage, Structures, and Conductors

Design voltage of the proposed transmission line is 115 kV. The Project would have a total length of approximately 14 miles, and would require new right-of-way for the entire distance of the transmission line and newly purchased land parcels for the substation and switching station. The entire line and associated facilities would be within St. Louis County, Minnesota.

Two structure types are being considered for the Project: wood H-frame and wood single pole. Dependent upon land use type, topography, right-of-way constraints and other design-dependent features, each of these transmission line structure designs would be appropriate in certain areas.

The two pole wood H-frame structure design is suited for areas with rugged topography and/or for areas requiring longer spans to avoid or minimize placement of structures in wetlands or waterways. The average span would be 600–700 feet, with 1,000-foot spans achievable with certain topography. The structure height would average 60–80 feet with taller structures required for the exceptionally long spans and in circumstances requiring additional vertical clearance. Figure 7-1 shows a cross section drawing of a typical GRE 115 kV H-Frame structure being considered for this Project.

The single pole design (GRE-THP or THP-B) is suited for areas where available right-of-way is limited, such as where rights-of-way are shared along roads in developed areas. Two insulator types could be used depending on requirements: a standard post insulator (THP design) and a braced post insulator (THP-B design). The advantage of the THP-B braced post insulator design is that longer span lengths can be achieved, however structure cost in increased. Average structure height would be 65–90 feet to achieve average span lengths of 300–400 feet. Specific structure heights and span lengths may exceed the average due to land use requirements and topography. Figures 7-2 and 7-3 show cross section drawings of a typical GRE 115 kV single pole THP and a THP-B structure being considered for this Project.

In addition to the two main structures under consideration for the Project, there may be limited use of a single pole structure with low voltage single phase or three phase distribution underbuild that directly supplies area electric customers. This single pole design is used in areas where existing land use development restricts the placement of two separate power line circuits; a high voltage circuit and a lower voltage (distribution line) circuit. The advantage of this design is less right-of-way requirement; however, there are significant operating, maintenance, and cost factors to consider. The higher voltage circuit is “stacked” on top of the lower voltage distribution circuit, resulting in a taller pole (averaging 75–90 feet in height) and shorter spans (250–350 feet). Another alternative would be to place the distribution line underground in specific areas.

Figure 7-1   115 kV Transmission H-Frame Structure

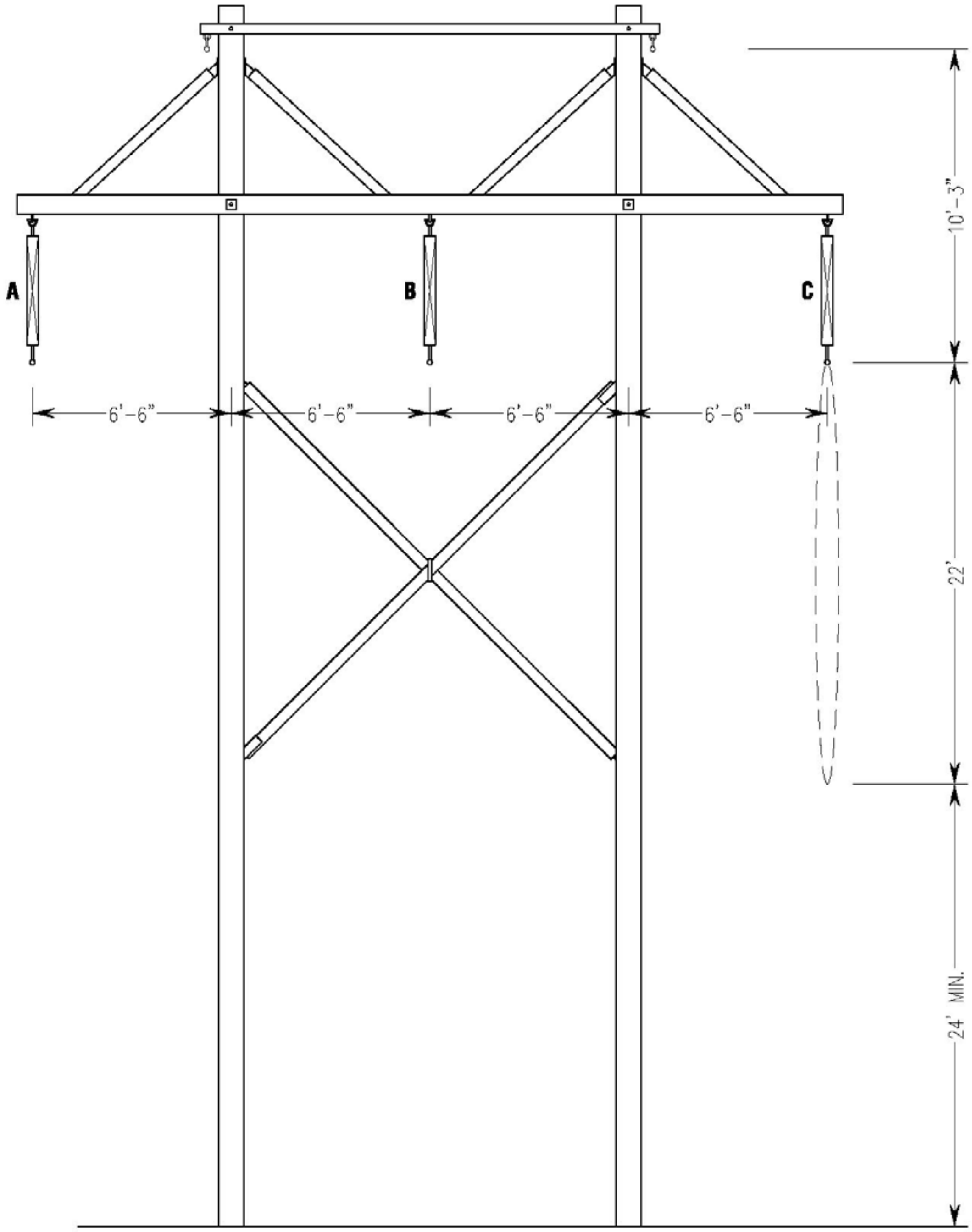


Figure 7-2 115 kV THP Single Pole Structure

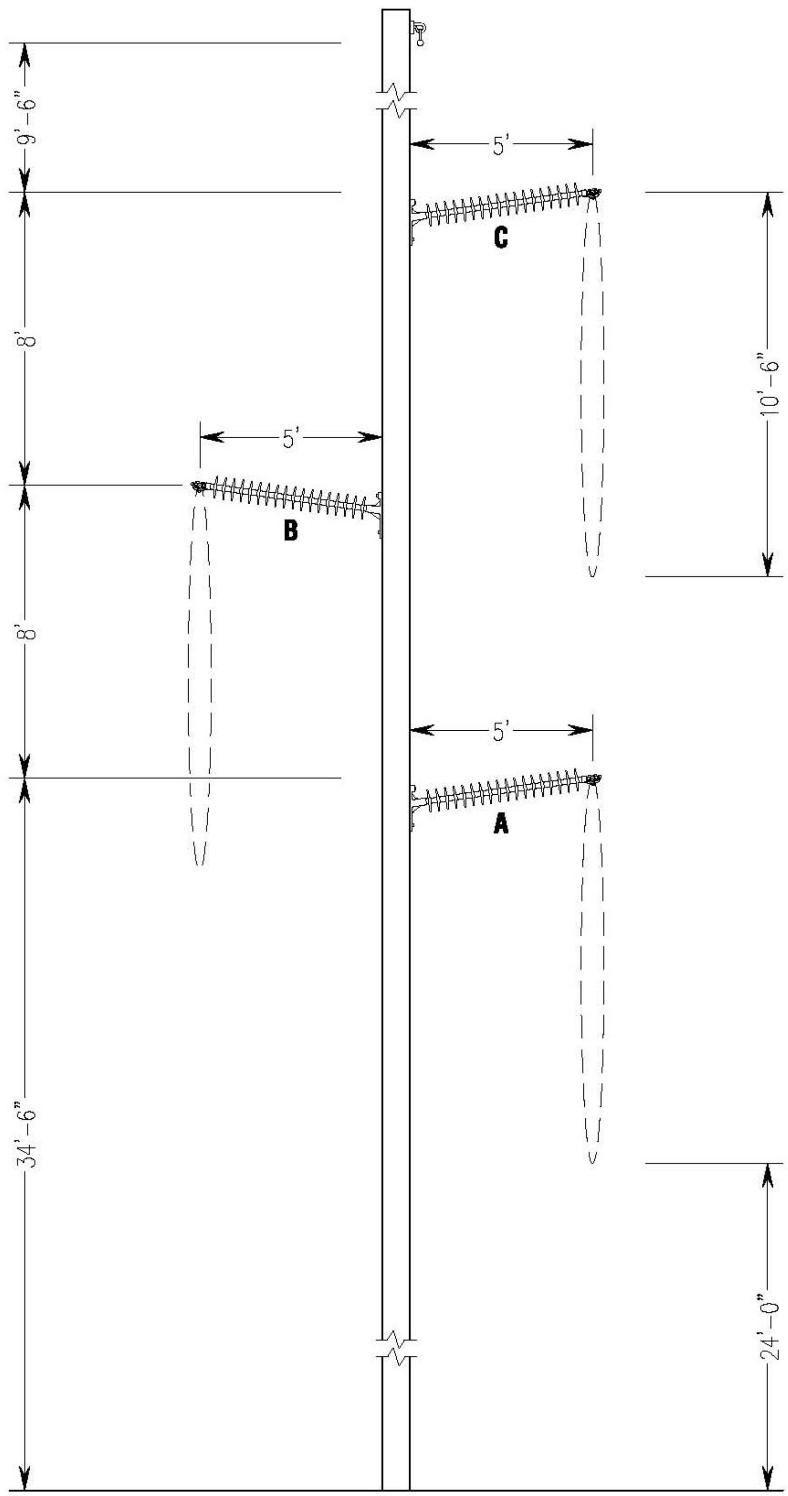
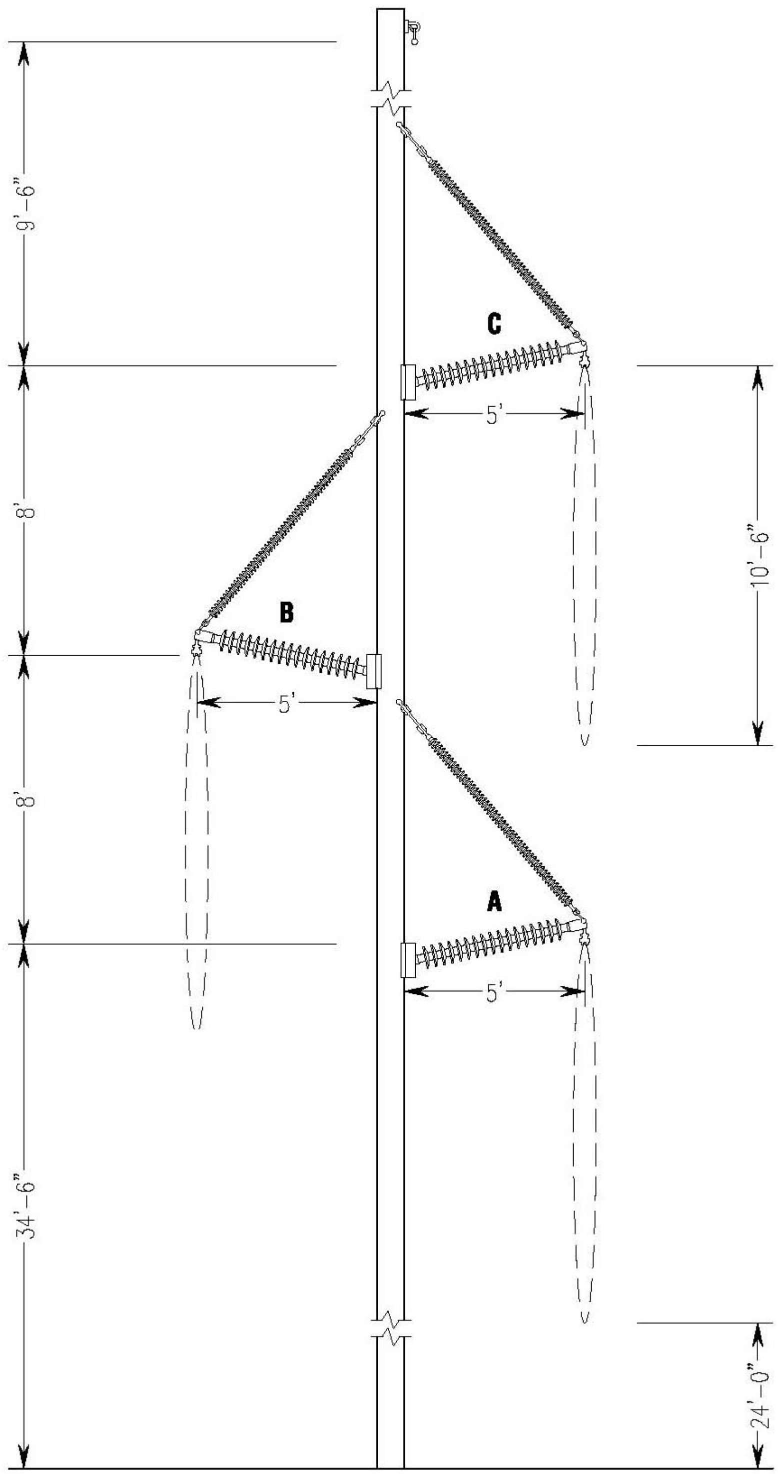


Figure 7-3 115 kV THP-B Single Pole Structure



The transmission line would utilize 795 aluminum conductor steel reinforced (ACSR) Drake conductors, which have an ampacity of 982 amps at 100 degrees C. This will limit maximum continuous electric power capacity of the line to 196 (MVA), provided there is not a more restrictive limit associated with the substation terminal equipment or transformation capacity. The line would use three single conductors (not bundled). Depending on structure type (single pole or H-frame), there would also be one or two shield wires (3/8″ high strength 7-strand steel) to protect the conductors from lightning. It is likely that one shield wire would be an optical shield wire (64mm2/528 OPGW 24 fiber), to be used for communications.

7.2 Transmission Structures

This section describes the type of transmission structure that is proposed for each of the four Project route areas. The final design may be refined following the ground survey and discussions with landowners.

7.2.1 Route Area 1 – Tower Substation to County Highway 26

The H-frame design is the preferred structure type for this route area (RS 15a and 16). This structure type is shown in Figure 7-1.

7.2.2 Route Area 2 – County Highway 26 to East Taylor Road

Single pole design is preferred at the crossing of County Highway 26 due to the constrained right-of-way and landowner request to minimize the right-of-way width (and removal of a planted screen of trees). Single pole design is also preferred along Bergstedt Road to minimize right-of-way width and associated tree clearing. The H-frame design is preferred in the area parallel to the recreational trail due to the extensive wetlands and unstable soils. This route area includes RS 22. The preferred structure types for this portion of the Project are shown in Figures 7-1, 7-2, and 7-3.

7.2.3 Route Area 3 – East Taylor Road to County Highway 21

Single pole design is preferred in the area of the Bergstedt Road and Highway 135 intersection due to limited right-of-way availability. The H-frame design is preferred for the area traversing the extensive wetlands west of the Levander Road. This route area includes RS 31 and 32. Structure types preferred for this portion of the Project are shown in Figures 7-1, 7-2, and 7-3.

7.2.4 Route Area 4 – County Highway 21 to Embarrass Switching Station

Due to the extensive wetlands and rugged terrain, H-frame design is preferred in this entire route area, which includes RS 42, 44a, 46 and 47. The H-frame structure type preferred for this portion of the Project is shown in Figure 7-1.

7.2.5 Construction Considerations

Clearances

The transmission lines will be designed to meet NESC standards (Institute of Electrical and Electronics Engineers, 2002). The NESC recommends minimum safety standards for clearances over roadways, buildings, signs, light standards, and other facilities. In addition, the Applicants will comply with their respective standards. MP has company standards that meet or exceed NESC requirements. GRE has company standards that meet or exceed NESC requirements, and also follows the RUS Design Manual for High Voltage Transmission Lines (US Department of Agriculture, 2005). This manual recommends clearances above the minimum NESC values to account for construction tolerances, such as a pole that is set deeper than originally specified.

Clearances over highways and roadways will exceed the 23 feet recommended by the NESC and RUS standards and may be limited by MNDOT or local county highway permitting. Although the existing standards give recommended clearances over buildings, GRE and MP generally do not locate transmission lines directly over a building unless it cannot be avoided. Horizontal clearances to buildings, signs, light standards, and other installations will be determined by calculating the blowout of the wire, structure deflection, and safe electrical clearance from the line.

Material Requirements

The construction of the transmission line will require the use of both renewable and non-renewable resources. Renewable resources consist of the wooden poles and non-renewable resources include insulators, conductors, shield wires, and related hardware.

7.3 Tower Substation

Initially, a 35 MVA 115/46 kV transformer would be installed in the proposed Tower Substation. It is anticipated that if this Project is approved, a 60 MVA 115/69 kV transformer would be installed in the proposed Tower Substation in the future. This would limit the proposed line to a capacity of 95 MVA. However, the substation would be designed for additional transformer capacity when/if future load growth, reliability, or security issues dictate its need. Therefore, it is conceivable the conductor and operating voltage could become the most restrictive element and limit maximum continuous power transfer to 196 MVA at some point in the future.

The expected initial maximum power flow on the proposed line in 2009 would be 30 MVA (assumes GRE proceeds with the 69 kV additions); well below the 95 MVA limit imposed by the transformers to be installed as part of this Project and anticipated 69 kV additions. The Tower Substation will be built using a “low-profile” design. It will be a conventional outdoor open-type air-insulated bus-and-switch arrangement laid out in an easily expandable configuration.

The primary components of the new substation will initially include:

- One 115 kV breaker, single bus design to accommodate one 115 kV transmission line termination, and provisions for a future GRE 69 kV circuit.
- One 115 kV/46 kV 35 MVA transformer with load tap changing equipment and associated switching and protection equipment.
- Two 46 kV line feeders and associated protection equipment.
- Grading, fencing, a control building, and steel structure installation.

The Tower Substation will be laid out to accommodate a future 115/69 kV transformer, distribution transformer, and associated protection and line termination equipment.

7.4 Embarrass Switching Station

The purpose of the Embarrass Switching Station is to sectionalize the three terminal 115 kV Line #34 currently supplying the Babbitt 115/46 kV Substation into three independent lines (each protected by its own circuit breaker), and to connect the new 115 kV line from Tower into the region's 115 kV electric supply system (also protected by its own circuit breaker). This will provide a substation with two independent 115 kV connections to the region's 115 kV transmission grid; one from Virginia and one from Laskin. The 115 kV transmission line to Babbitt and the new 115 kV line to Tower would be supplied with electric energy by these two independent 115 kV sources.

Without this switching station, MP Line #34 could not be used as a source for the new 115 kV line to the Tower Substation, because an outage of Line #34 would result in loss of the 115 kV supply to both Babbitt and to Tower. With the switching station, a loss of the connection to Babbitt will not result in the outage of the 115 kV supply to Tower, and likewise loss of the line to Tower will not result in an outage of the 115 kV supply to Babbitt, because each line has its own circuit breaker and the switching station is supplied by two 115 kV connections to the region's transmission grid (one to the Virginia 115 kV Substation and one to the Laskin 115 kV Substation).

The Embarrass Switching Station will be constructed using a "low-profile" design, with a conventional outdoor air-insulated ring bus arrangement. The main components of the switching station will include:

- Four 115 kV transmission line terminations.
- Four 115 kV breakers with associated relaying.
- Grading, fencing; a control building, and steel termination structures.

7.5 Electric and Magnetic Fields

Electric and magnetic fields (EMF) are present around any electrical device, and can occur indoors and outdoors. Electric fields are the result of voltage or electrical charges, and the intensity of the electric field is related to the operating voltage of the line or the device. Magnetic fields are the result of the flow of electricity or current that travels along transmission lines, distribution (feeder) lines, substation transformers, house wiring, and household electrical appliances. The intensity of a magnetic field is related to the current flow through the conductors (wire).

Considerable research has been conducted throughout the past three decades to determine whether exposure to power-frequency (60 hertz) electric and magnetic fields cause biological responses and health effects. Epidemiological and toxicological studies have shown no statistically significant association or weak associations between EMF exposure and health risks.

In 1999, the National Institute of Environmental Health Sciences (NIEHS) issued its final report on “Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields” in response to the Energy Policy Act of 1992. NIEHS concluded that the scientific evidence linking EMF exposures with health risks is weak and that this finding does not warrant aggressive regulatory concern. However, because of the weak scientific evidence that supports some association between EMF and health effects and the common exposure to electricity in the United States, passive regulatory action, such as providing public education on reducing exposures, is warranted.

Minnesota, California and Wisconsin have all recently conducted literature reviews or research to examine this issue. In 2002, Minnesota formed an Interagency Working Group to evaluate the body of research and develop policy recommendations to protect the public health from any potential problems resulting from HVTL EMF effects. The Working Group consisted of staff from various state agencies. The Working Group published its findings in a White Paper on EMF Policy and Mitigation Options (White Paper 1) in September 2002 (Minnesota Department of Health, 2002).

The findings of the Working Group are summarized below.

> *Research on the health effects of EMF has been carried out since the 1970s. Epidemiological studies have mixed results – some have shown no statistically significant association between exposure to EMF and health effects, some have shown a weak association. More recently, laboratory studies have failed to show such an association, or to establish a biological mechanism for how magnetic fields may cause cancer. A number of scientific panels convened by national and international health agencies and the United States Congress have reviewed the research*

carried out to date. Most researchers concluded that there is insufficient evidence to prove an association between EMF and health effects; however many of them also concluded that there is insufficient evidence to prove that EMF exposure is safe (White Paper 1).

The Minnesota Environmental Quality Board (EQB) has addressed the matter of EMF with respect to new transmission lines in a number of separate dockets over the past few years [Docket Nos. 03-64-TR-Xcel (161 kV Lakefield line); 03-73-TR-Xcel (345 kV Buffalo Ridge line); 04-84-TR-Xcel (115 kV Buffalo to White line) and 04-81-TR-Air Lake-Empire (115 kV line in Dakota County)]. The findings of the EQB and the discussion in the Environmental Assessments prepared on each of those projects are pertinent to this issue with respect to the proposed Project. Documents from those matters are available on the Commission webpage: energyfacilities.puc.state.mn.us.

In June 2005, in Docket No. 03-73-TR-Xcel for the 345 kV Buffalo Ridge line, the EQB made the following findings with regard to EMF:

118. No significant impacts on human health and safety are anticipated from the Project. There is at present insufficient evidence to demonstrate a cause and effect relationship between EMF exposure and any adverse health effects. The EQB has not established limits on magnetic field exposure and there are no federal or Minnesota health-based exposure standards for magnetic fields. There is uncertainty, however, concerning long-term health impacts and the Minnesota Department of Health and the EQB all recommend a “prudent avoidance” policy in which exposure is minimized.

119. In previous routing proceedings, the EQB has imposed a permit condition on high voltage transmission line permits limiting electric field exposure to 8 kilovolts per meter (kV/m) at one meter above ground. This permit condition was designed to prevent serious hazard from shocks when touching large objects such as semi trailers or large farm equipment under extra HVTLs of 500 kV or greater. Predicted electric field densities are less than half of the 8 kV/m permit condition for both the 345 kV line and the 115 kV line.

When a conductive object, such as a vehicle or a metal fence are in close proximity to a transmission line, the electric field produced by the line can couple with the object and induce a voltage on it. The voltage that is induced on the object is dependent on many factors, including the weather condition, object shape, object size, object orientation, object to ground resistance, and capacitance and location along the right-of-way. If these objects are insulated or semi-insulated from the ground, and a person touched them, a small current would pass through the person’s body to the ground. This might be accompanied by a spark discharge and mild shock, similar to what can occur when a person walks across a carpet and touches a grounded object or another person.

The main concern with induced voltage on an object is not the level of the induced voltage, but the current flow through the person to ground if a person were to touch the object. To insure that any discharge does not reach unsafe levels, the NESC requires that any discharge be less than 5 milliamperes (ma). Based on the Applicants' 115 kV transmission line operating experience, the discharge from any large mobile object such as a bus or truck parked under or adjacent to the line would unlikely reach levels considered to be an annoyance, and would be significantly less than the 5 ma NESC limit. The Applicants would also assure that any fixed object, such as a fence or other large permanent conductive object in close proximity to or parallel to the line, would be grounded such that excessive discharges would not occur.

High intensity electric fields can have adverse impacts on the operation of pacemakers and implantable cardioverter/defibrillator (ICD). Interference to implanted cardiac devices can occur if the electric field intensity is high enough to induce sufficient body currents to cause interaction.

Modern bipolar devices are much less susceptible to interactions with electric fields. Medtronic and Guidant, manufacturers of pacemakers and ICDs, have indicated that electric fields below 6 kV/meter are unlikely to cause interactions affecting operation of most of their devices.

Older unipolar designs are more susceptible to interference from electric fields. Research completed by Toivoen et. al (Toivoen et. al 1991) indicated that the earliest evidence of interference was in electric fields ranging from 1.2 to 1.7 kV/meter. Figure 7-4 shows that the e-field for all structure and right-of-way alternatives are well below levels that modern bipolar devices are susceptible to interactions with electric fields. For older style unipolar designs, the e-field just exceed levels that Toivoen et. al has indicated may produce interference. However, a recent paper concludes that the risk of interference inhibition of unipolar cardiac pacemakers from high voltage power lines in everyday life is small[1]. In the unlikely event a pacemaker is impacted, the effect is typically a temporary asynchronous pacing (commonly referred to as reversion mode or fixed rate pacing). The pacemaker would return to its normal operation when the person moves away from the source of the interference.

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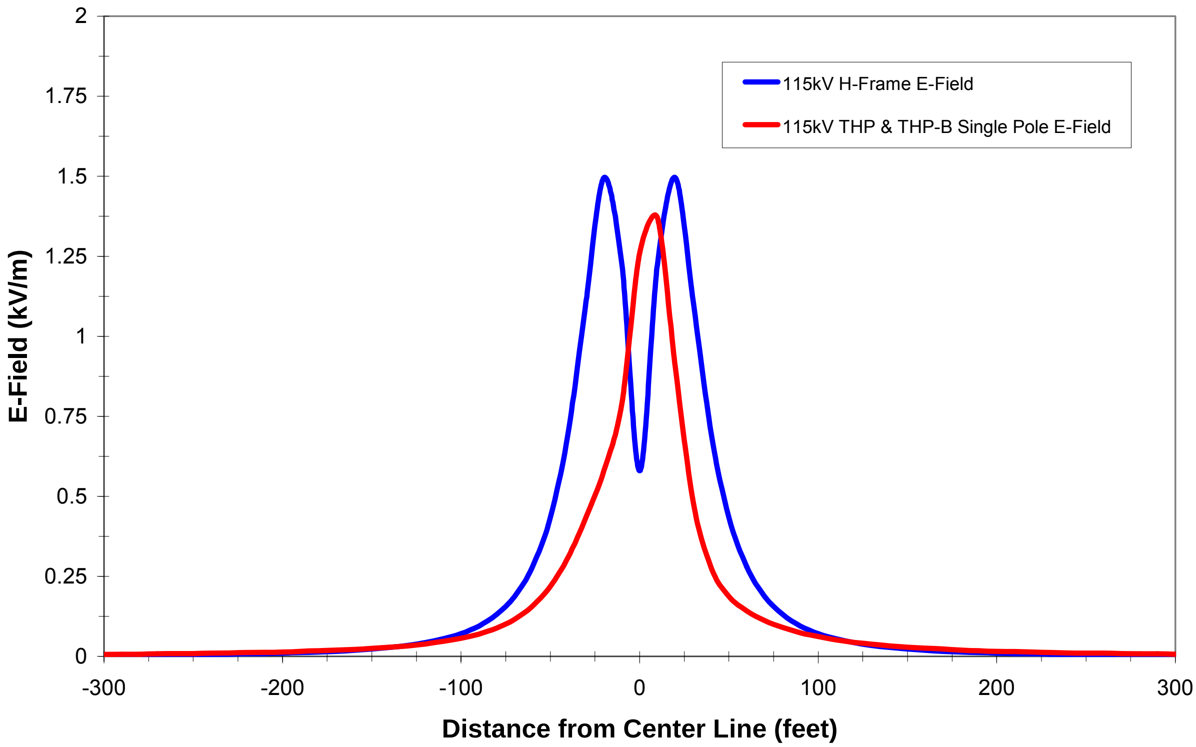
[1] Scholten A, Joosten S, Silny J, Unipolar cardiac pacemakers in electromagnetic fields of high voltage overhead lines, Journal of Medical Engineering and Technology, 2005, 29(4):170-5

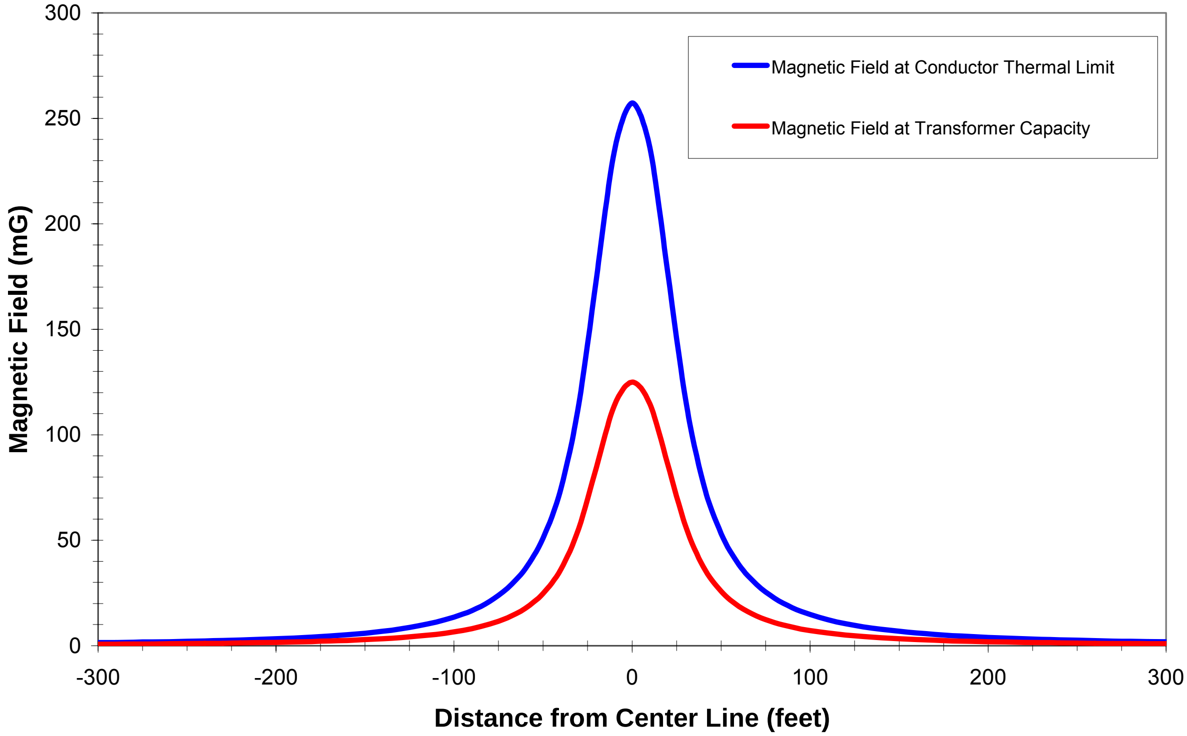
Figure 7-4   Electric Field – Proposed 115 kV Structures



The magnetic field profiles around the proposed lines for the structure and conductor configurations being considered for the Project, H-frame and single pole, are shown in Figures 7-5 and 7-6. Because the magnetic field is dependent on current flow, the expected magnetic field was calculated for two conditions: current flow at the conductor's thermal capacity (982 amps) and current flow at the 95 MVA (477 amps) limit imposed by the substation transformer capacity. The 95 MVA limit is based on the 35 MVA 115/46 kV transformer to be added as part of this Project and the 60 MVA 115/69 kV transformer to be added in the future by GRE if this Project is approved.

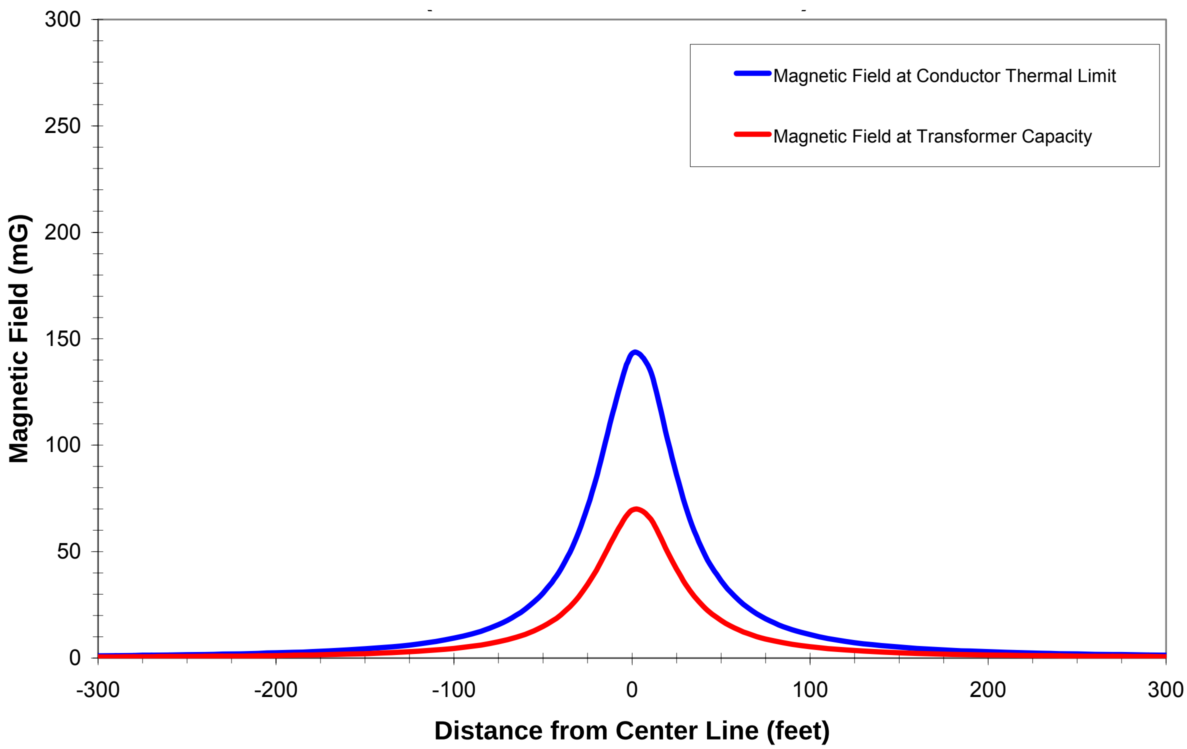
Load flow analysis indicates that actual current flows on the line will be significantly less than the flows depicted in the graphs (see Figures 7-5 and 7-6). Because the magnetic field produced by the transmission line is dependent on the current flowing on its conductors, the actual magnetic field will be less than shown in the graphs. Also, magnetic field profile data show that magnetic field levels decrease rapidly (inverse square of the distance from source) from the centerline.

Figure 7-5 Magnetic Field – Proposed 115 kV Line with H-Frame Structure



Load flow analysis indicated that when the Project is placed in service, expected system intact continuous peak flows on the proposed 115 kV line will be 151 amps (30 MVA), or approximately 32% of the 477 amp limit imposed by the transformer capacity. Likewise, load flow analysis indicates that in 2025, the expected transmission line flows would be 226 amps (45 MVA), or approximately 50% of the flow at the transformers capacity. Because the strength of the magnetic field is directly proportional to the current flow, the actual magnetic field will initially be approximately 32% of the magnetic field depicted in the graph (with current flow at the 477 amp limit imposed by the transformer capacity), and increase to approximately 50% of the level depicted by 2025.

Figure 7-6 Magnetic Field – Proposed 115 kV Line with Single Pole THP and THP-B Structure



7.6 Ozone and Nitrogen Oxide Emissions

Corona, which may produce ozone and oxides of nitrogen, consists of an ionic or electrical discharge from the surface of a transmission line conductor. It occurs when the electric field intensity or surface gradient on the conductor exceeds the breakdown strength of air. For a 115 kV transmission line, the conductor surface gradient is usually below the air breakdown level. Some imperfection, such as loose conductor support hardware or water droplets, is necessary to cause corona. When corona occurs, it will be within a few centimeters or less immediately surrounding a conductor. Ozone also forms naturally in the lower atmosphere from lightning discharges and from reactions between solar ultraviolet radiation and air pollutants such as hydrocarbons from auto emissions.

The natural production rate of ozone is directly proportional to temperature and sunlight and inversely proportional to humidity. Therefore, humidity (or moisture), the same factor that increases corona discharges from transmission lines, inhibits the production of ozone. Ozone is a very reactive form of oxygen and combines readily with other elements and compounds in the atmosphere. Because of its reactivity, ozone is relatively short-lived.

On July 18, 1997 the Environmental Protection Agency (EPA) promulgated a regulation (62 Federal Register 38856) replacing the 1-hour ozone 0.12 parts per million (ppm) standard with an 8-hour standard at a level of 0.08 ppm. The form of the 8-hour standard is based on the 3-year average of the annual fourth-highest daily maximum 8 hour average ozone concentrations measured at each monitor within an area. Calculations using the BPA *Corona and Field Effects Program Ver. 3* (USDOE, BPA, Undated) for a standard single circuit 115 kV project predicted the maximum concentration of 0.006 ppm near the conductor and 0.002 ppm at one meter above ground during foul weather or worst case conditions with rain at one inch per hour. During a mist (rain at 0.01 inch per hour) the maximum concentrations decreased to 0.0002 ppm near the conductor and 0.0001 ppm at one meter above ground level. For both cases, the ozone levels are below EPA standards.

Most calculations for the production and concentration of ozone assume high humidity or rain with no reduction in the amount of ozone due to oxidation or air movement. These calculations would therefore overestimate the amount of ozone that is produced and concentrated at ground level. Studies designed to monitor the production of ozone under transmission lines have generally been unable to detect any increase due to the transmission line facility.

7.7 Radio/TV Interference

The most significant factor with respect to radio and television interference is not the magnitude of the transmission line induced noise, but how the transmission line induced noise compares with the strength of the broadcast signal. Very few radio noise problems have resulted from existing 115 kV transmission lines, as broadcast signal strength within a radio station’s primary coverage area is great enough that adequate signal to noise ratios are maintained.

If radio interference from transmission line corona does occur with AM radio stations presently providing good reception, satisfactory reception can be obtained by appropriate modification of (or addition to) the receiving antenna system.

Interference with FM broadcast station reception is generally not a problem because:

- corona generated radio frequency noise currents decrease in magnitude with increasing frequency and are quite small in the FM broadcast band (88-108 megahertz (MHz)), and
- the excellent interference rejection properties inherent in FM radio systems make them virtually immune to amplitude type disturbances.

A two-way mobile radio located immediately adjacent to and behind a large metallic structure (such as a steel tower) may experience interference because of signal blocking effects. Movement of either mobile unit so that the metallic structure is not immediately between the two units should restore communications. This would generally require a movement of less than 50 feet by the mobile unit adjacent to a metallic tower. Because no steel towers are anticipated for the proposed 115 kV line, this will not be a problem. Noise in the frequency range of cellular type phones is almost non-existent and the technology used by these devices is superior to that used in two-way mobile radio.

As in the case with AM radio interference, corona-generated noise could cause interference with TV picture reception because the picture is broadcast as an AM signal. The level of interference depends on the TV signal strength for a particular channel (TV audio is an FM signal that is typically not impacted by transmission line radio frequency noise).

Due to the higher frequencies of the TV broadcast signal (54 MHz and above), 115 kV transmission lines seldom result in reception problems within a station's primary coverage area. In the rare situation that the proposed transmission line would cause TV interference within a broadcast station's primary coverage area where good reception is presently obtained, MP and GRE would work with the affected party to correct the problem. Usually any reception problem can be corrected with the addition of an outside antenna.

TV picture reception interference can also be the result of a transmission structure blocking the signal to homes in close proximity to a structure. Because the structures proposed for this Project would be wood, this is unlikely to occur. However, measurements can be made to verify whether a structure is the cause of reception problems. Reception problems can usually be corrected with the addition of an outside antenna, an amplifier, or both.

Loose and/or damaged hardware may also cause television or radio interference. If television or radio interference is caused by or from the operation of the proposed 115 kV line within a broadcast station's primary coverage area where good reception is presently obtained, MP and GRE will inspect and repair any loose or damaged hardware in the transmission line, or take other necessary action to restore reception to the present level.