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OF
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ON BEHALF OF ONCOR ELECTRIC DELIVERY COMPANY LLC

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Underground Electric Transmission Lines

The discussion below addresses the challenges of placing a high-voltage / high-current transmission line underground. The purpose of this information is to describe key design concepts central to understanding why Oncor does not consider it technically feasible to place the proposed CREZ transmission line underground.

A. DESIGN COMPONENTS

1. Three-Phase Design

Any design for the transmission of electricity must use a three-phase alternating circuit configuration to be compatible with the electrical system in operation throughout the United States. Electricity is generated as a three-phased circuit, transmitted in three-phase configurations, and substation load centers are designed to accept three-phase electricity for distribution to end users. A typical three-phase design, applicable to the proposed 345 kV transmission line, is shown in the upper half of Figure 1. This figure shows a lattice tower (typically 125 feet in height) with one circuit on each side of the tower, with each circuit characterized by three phases of paired or "bundled" conductors (i.e., electrical transmission conductors made of strands of steel and aluminum wire bundles).

2. Overhead Conductor Design

Each of the six conductors within a circuit has an inner core of 19 stranded steel wires to provide structural strength to the conductor. Wrapped around the steel core are 54 strands of aluminum alloy wire which serve to conduct electrical energy. Each conductor is 1.545 inches in diameter, and there is no insulating covering applied to the exterior. The conductor pairs are suspended from the steel tower by insulator strings which prevent grounding of electricity through the tower. Conductor pairs are connected throughout and function as if the pair of conductors were a single cable. To prevent electrical arcing between phases, the minimum distance between phases is about 22 feet.

Aluminum readily conducts electricity and is light in weight, making it the metal of choice for above ground transmission lines. However, all electrical conducting media pose resistance to the flow of electricity, and this resistance generates heat. For a given metal conductor of electricity, the amount of heat generated by electricity passing through it increases by the square of the current (i.e., amperage). For example, for every unit of heat created by a current of 1,000 amperes, a current of 5,000 amperes would create 25 (i.e., 5^2) units of heat. The effect of heat generated by above ground high-amperage transmission lines on the transmission of electric power is minimized because power line heat is readily removed by surrounding air, particularly if some wind is blowing.

3. Underground Transmission Lines and Transition Stations

The reconfiguration of an overhead transmission line to an underground transmission line requires the construction of a transition station. Heat dissipation is a primary consideration in the design of the underground transmission line. In essence, what works for overhead transmission lines to dissipate the heat of electrical resistance will not work underground. Unlike the air, the soil is a relatively poor agent for dissipating the heat radiating from a transmission line, and soils that are higher in clay content are less efficient in dissipating heat than sand.

The flow of electricity through the aluminum above ground conductors must be maintained in the copper conductors underground. Although vastly more expensive than aluminum as well as much heavier in weight, copper is a much better conductor of electricity and would pose less resistance to electrical flow. Consequently, the amount of heat generated by wire resistance would be less for copper cables than for aluminum cables. The largest copper cables currently available would be slightly over two inches in diameter, and comprised of a bundle of individual copper wires. This configuration would allow the flow of approximately 1,000 amperes per copper cable, provided that adequate dissipation of heat is available.

At the transition station, the overhead transmission line configuration shown on the upper portion of Figure 1 would be converted to the underground transmission line configuration as shown in the lower portion of Figure 1 for a 5,000-ampere transmission line circuit. The steel underground transmission pipes would be spaced apart to ensure dissipation of heat and to avoid the overlapping of heat fields around each cable. It is estimated that these cables would be placed a minimum of 20 feet apart, which would require the ROW to be at least 200 feet wide as there would be ten underground transmission line pipes (i.e., five for each circuit). There would be three cables within each of the steel underground pipes.

The underground cables would utilize two types of insulation to preserve the integrity of the cables. The copper portion of each cable would be wrapped in over an inch of paper insulation, which would be surrounded by a thin semi-permeable plastic sheath. The underground pipes would be filled with dielectric fluid to provide insulation integrity and assist in heat dissipation. The transition station would be equipped with pumps to maintain the high pressure dielectric fluid filled system (i.e., 200 pounds per square inch pressure) within the underground pipes. Pressurization of the fluid within the pipes is necessary to ensure saturation of the paper insulation that surrounds each of the transmission cables. Within this pressurized system, heat that is generated in the copper cable radiates away from the cable into the liquid-filled cavity of the steel pipe and then through the pipe into the surrounding soil. In order for the heat transfer functions to operate properly, there must be sufficient movement of heat away from the pipes to allow the internal cooling of the cables to maintain the required cable ampacity.

Factors such as the type of surrounding soil conditions, adjacent underground utilities and the depth of installation all affect the copper cable's ability to dissipate heat. A lower thermal rating for underground transmission lines mean they do not have as much capacity as overhead lines in supporting high ampacity operations. Burying a transmission line near the surface of the soil (i.e., within four to five feet) allows heat to migrate to the soil-air interface and dissipate. To date, 3,200 amperes is the highest capacity 345kV underground transmission line that Oncor has in operation; this line was installed by creating a trench (approximately four to five feet deep) in which to place the transmission line pipes and backfilling the trenches with sand to facilitate heat dissipation. As line routing forces underground lines to cross highways, rivers, or other surface and subsurface obstacles, the depth of the line must be increased to accommodate these obstacles. This added depth, along with the inability to trench and backfill with sand, adversely impacts the ability of the underground line to maintain design ampacity and remain a reliable transmission facility.

It is expected that "hot spots" would nevertheless develop within these underground pipes due to the lack of adequate dissipation of heat. The topographical configuration of the area would require the directional drilling of the transmission line pipes to an estimated depth of at least five feet below the lowest elevation. Currently, there is no site-specific geotechnical information currently available as to the type and texture of soils and at what depths they may occur, but it is expected that layers of heavy-textured soils may be encountered which could contribute to exacerbating hot spots as heat builds up at specific points along the underground transmission line. When this occurs, the insulation around the transmission cable could potentially be damaged to the degree that arcing between phases would cause a fault in the transmission line that would shut down the affected circuit until the cable could be repaired or replaced. Given the experience with other underground transmission lines, Oncor does not believe that an underground transmission line with 5,000 amperes capacity would be sufficiently reliable to serve as an operational component of the CREZ transmission line system.

B. OTHER CONSIDERATIONS

Aside from the foregoing challenges that affect the electrical capacity and reliability of a buried transmission line, there are several other obstacles that would make it difficult to construct or maintain buried power transmission lines. These additional considerations are discussed below.

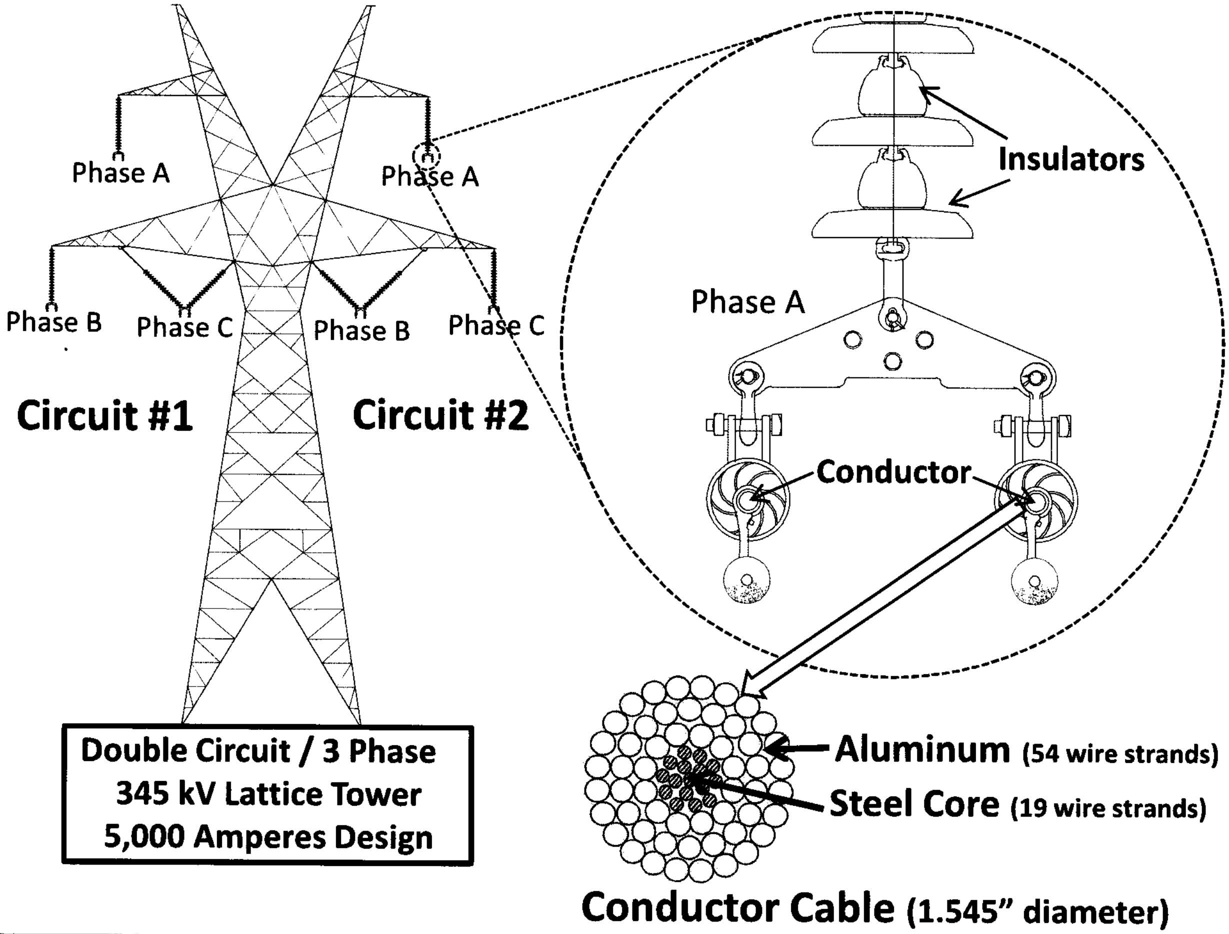
The depth and possible length of directional drilling necessary to install the underground steel pipes creates several difficult operational challenges. Directional drilling for utilities requires greater spacing between entry and exit transition stations in order to achieve increased depths of drilling. Spacing between pipes becomes a limiting factor because the copper cables that are placed into the pipes must be manufactured as a single continuous cable, since subsurface splicing of these cables is not feasible. These cables would be a minimum of three inches in diameter with a limited bend radius, and pulling these three-phase cables through the steel pipes is a difficult process. Specifically, the length of the pipes would require an increase in the tension necessary to pull the cables through the pipes, and this increased tension could potentially result in damage to the cables. This is important because it is difficult to detect damage to the cables that may occur during installation. Similarly, a critical element in comparing underground and overhead lines is that it typically takes more time to locate, diagnose and repair a problem or fault on an underground transmission line. Repair of failed underground lines can be environmentally disruptive, costly, and may require shutting down the entire the transmission line for lengthy periods of time.

Placing high-voltage high-amperage transmission lines underground would also create potential environmental hazards that do not exist with overhead transmission of electricity. For example, the magnitude of magnetic fields at the ground line is much higher for underground transmission systems than for comparable overhead construction. The precise strength of the magnetic field at the trails at ground level would depend on the depth of burial, but the soil medium would have little insulating effect on the attenuation of magnetic fields. Dielectric fluid is generally oil-based and could have environmental impacts in the event of a leak or rupture. Finally, transition stations would need to be placed on fill to ensure elevation above the 100-year floodplain, and compensating excavation would likely be required within the floodplain to offset that fill.

Installation costs for a 5,000 amp 345kV double circuit underground transmission line are estimated to be 30 to 35 times the cost to install an equivalent overhead transmission line depending on the length of the line and the complexity of the installation. These costs would be added to the rate base for the electricity consumers, as would any increased costs associated with maintenance of the underground transmission lines.

C. SUMMARY

Placing the proposed transmission line underground is not considered a feasible alternative because the technology has not been developed (nor is it likely to be developed in the near term) to adequately compensate for the heat that would be generated by a buried high-voltage / high-amperage transmission line. It is expected that the safe and reliable design of an underground transmission line would ultimately require a reduction in voltage and/or amperage. It is not considered technically feasible to construct a reliable 345 kV, 5,000-ampere underground facility that would meet the requirements of the national electrical system and specifications established by the American National Standards Institute.



TRANSITION STATION

Changes configuration of each 3-phase circuit (3 pairs of aluminum/steel conductors), to semi-permeable insulated copper wires immersed in pressurized dielectric fluid, while retaining the 3-phase arrangement within each of 5 steel underground pipes.

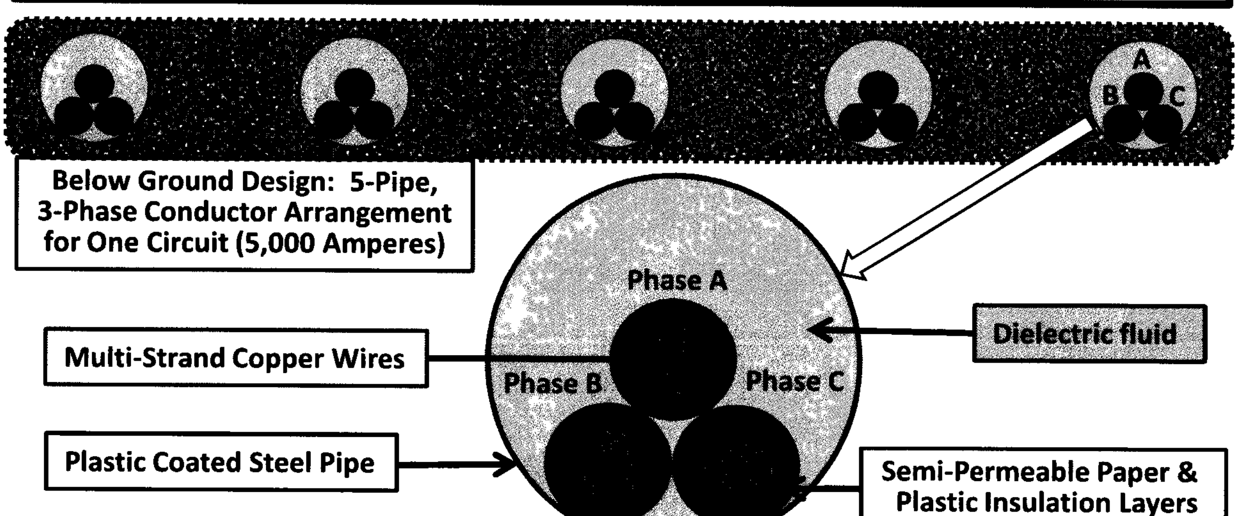


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Figure 1. Components of Above-Ground and Below-Ground Transmission Lines