PUBLIC SERVICE COMMISSION
OF WEST VIRGINIA
CHARLESTON

Case No. 07-0508-E-CN

TRANS-ALLEGHENY INTERSTATE LINE COMPANY

Application of Trans-Allegheny Interstate Line Company for a certificate of public convenience and necessity under W. Va. Code § 24-2-11a authorizing the construction and operation of the West Virginia segments of a 500 kV electric transmission line and related facilities in Monongalia, Preston, Tucker, Grant, Hardy, and Hampshire Counties, and for related relief

REBUTTAL TESTIMONY OF JAY WILLIAMS

January 4, 2008

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Jay Williams. My business address is Power Delivery Consultants, Inc. ("PDC"), 28 Lundy Lane, Ballston Lake, New York 12019.

Q. WHAT IS YOUR POSITION AT PDC?

A. I am employed by and a principal engineer with Power Delivery Consultants, Inc. ("PDC"). PDC provides engineering and consulting services to electric utilities, research organizations, merchant power producers, and manufacturers. Our practice areas include overhead line and underground cable design, power transformer ratings, and transmission and distribution-related engineering support for circuit uprates, operating and maintenance, failure investigation, and training.

Q. HAVE YOU PREVIOUSLY FILED TESTIMONY IN THIS PROCEEDING?

A. No. I have not.

EDUCATION AND EXPERIENCE

Q. PLEASE SUMMARIZE YOUR EDUCATION AND PREVIOUS PROFESSIONAL EXPERIENCE.

A. I earned a Bachelor of Science degree in engineering from Brown University and an MBA from New York University. I worked as a cable engineer at Consolidated Edison Company of New York, Inc. ("Con Edison") from 1965 until 1973, and was in charge of the transmission cable group when Con Edison was installing major amounts of 345-kV cable. I worked at Power Technologies, Inc. from 1973 until 1992 and was in charge of the cable group when I left in 1992 to form PDC with another cable specialist. At PDC, I head a group of engineering professionals, including five engineers whose entire collective workload is spent on transmission cable systems. I have developed and present several courses each year on underground power transmission, and have written more than fifty technical papers, articles, and book sections on underground transmission cables. I am a Fellow of the Institute of Electrical and Electronics Engineers, Inc. ("IEEE") and a registered Professional Engineer in New York and Ohio. My resume is attached to this testimony as TrAILCo Rebuttal Exhibit JW-1.

Q. HAVE YOU PREVIOUSLY APPEARED AS A WITNESS BEFORE ANY OTHER REGULATORY AGENCIES?

A. Yes. I testified as an expert witness on behalf of the Vermont Department of Public Service for the cable crossing at Grand Isle as part of the PV-20 line application and regarding an application by the Vermont Electric Power Company, Inc. and Green Mountain Power Company for authority to construct the Northwest Vermont Reliability Project. I have also testified as a cable expert for several utilities evaluating underground transmission lines. I assisted Northeast Utilities as their expert witness on cable systems for major 345 kilovolt ("kV") installations as part of the Southwest Connecticut Reliability Project.

Q. WILL YOU BE USING THE SAME TERMS IN YOUR DIRECT TESTIMONY AS SET FORTH IN THE TABLE OF NOMENCLATURE ATTACHED TO THE APPLICATION?

A. Yes. In addition, I may define other specific terms in my direct testimony.

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR REBUTTAL TESTIMONY.

A. My rebuttal testimony addresses and expands upon the observations of Staff witness William M. Lewis regarding the feasibility of placing TrAIL underground or, in the alternative, configuring TrAIL as an overhead direct current ("DC") line. This rebuttal testimony will also respond to the general assertion in the direct testimony of Thomas M. Hildebrand that "there is a real possibility" that TrAILCo would be required to place the line underground in other jurisdictions by detailing the significant technical and operating impediments to placing TrAIL underground.

REBUTTAL

Q. WOULD YOU SUMMARIZE STAFF WITNESS LEWIS' DIRECT TESTIMONY ON THE TOPIC OF PLACING TRAIL UNDERGROUND.

A. Mr. Lewis notes that the feasibility of undergrounding an electric transmission line at the size, length, and capacity of TrAIL poses many questions. He also observes that there is no underground 500 kV transmission line comparable to TrAIL is currently operating in the United States and goes on to briefly describe the limited applications of underground transmission conductor at lower voltages in this country and elsewhere. Mr. Lewis also estimates that the range of costs to place TrAIL underground would be five times greater than an overhead installation. Finally, Mr. Lewis briefly summarizes the problems that would be associated with constructing TrAIL as a direct current ("DC") line, either underground or overhead.

Q. DO YOU DISAGREE WITH MR. LEWIS' ASSESSMENT OF THE FEASIBILITY OF PLACING TRAIL UNDERGROUND?

A. No, I do not disagree with Mr. Lewis' conclusions. I think it is important for the record in this proceeding, however, to amplify on the many challenges to placing a transmission line of TrAIL's intended voltage, capacity, and length underground.

Q. IS IT POSSIBLE TO PLACE ALL OR ANY PORTION OF TRAIL UNDERGROUND?

A. I cannot state that it would be impossible to place portions of the TrAIL project underground. However, as summarized by Mr. Lewis, there are numerous impediments to placing 500 kV cables underground and the disadvantages of such an installation, for all practical purposes, make the placement of any portion of the TrAIL project underground infeasible for the transmission grid reliability purposes intended for TrAIL.

Q. ARE YOU AWARE OF ANY CIRCUMSTANCES IN THE UNITED STATES OR ELSEWHERE IN WHICH 500 KV CABLES HAVE BEEN PLACED UNDERGROUND?

A. Again, there are no current examples of the installation of 500 kV cables of any appreciable length in the United States and certainly none at the length of the route proposed for TrAIL. In fact, the only instance of cables of this voltage being placed underground of which I am aware in this country is a short length less than two miles long of 500 kV underground cables that were installed within the property of Grand Coulee Dam in the 1970s, from the generator transformers to a switchyard. Following a catastrophic failure and fire soon after installation, the replacement cables have operated satisfactorily. During that same period, a 500 kV gas-insulated line a few hundred feet long was installed on the West Coast, but it has since been abandoned. Outside of the United States, 500 kV cables have been installed underground on a limited basis in utility tunnels or under bridges for lengths of less than twenty five miles in Japan and Canada. In addition, 500 kV submarine cables of lengths limited to about 25 miles or less have been installed between Vancouver, British Columbia and Vancouver Island. As noted by Mr. Lewis, installations of underground transmission conductor in Europe have not exceeded 400 kV. The maximum length of any of these lines is less than 25 miles.

Q. WHAT ARE SOME OF THE DISADVANTAGES OF PLACING 500 KV CABLES IN A PROJECT SUCH AS TRAIL UNDERGROUND?

A. Beginning with construction-related disadvantages, placing electric cables underground requires a massive excavation of the entire length of the segments of right-of-way planned for underground installation, as compared to excavating material only at tower locations for an overhead line. To accommodate a 500 kV project with the power transfer capacity required of TrAIL, such an excavation would be particularly large in width. For example, as I explain below in my rebuttal testimony, several sets of cables would be required to provide the power transfer capability of the three-phase overhead circuit planned for TrAIL. These cables would be spliced together in fifteen hundred foot sections and would be placed into individual plastic conduits. Each set of cables could require cement vaults approximately every fifteen hundred feet, at the points of splicing, that would be approximately 35 feet long by 8 feet in width and height. The extreme elevation changes along the West Virginia line route will present challenges in anchoring the cables to prevent damage from their sliding downhill during operation, in addition to the problems in civil works and cable installation. The extensive excavation required to place cables underground could also severely affect streams, wetlands, and other environmentally sensitive areas along a proposed right-of-way. Finally, as compared to a relatively limited number of access roads that would be required for subsequent maintenance and repair operations along an overhead right-of-way, permanent roads would be required along the entire lengths of any underground segments for the line.

Q. ARE THERE ELECTRICAL AND OPERATIONAL DISADVANTAGES TO PLACING 500 kV CABLES UNDERGROUND?

A. Yes, there are several. Because they cannot dissipate heat as effectively as conductors in an above-ground open air configuration, an underground cable is able to carry far less power than a similarly-sized overhead line. Mr. Lewis described the necessity of three sets of three underground cables each to provide a 3,400 MVA capacity for TrAIL. My estimate is that perhaps as many as four to six sets of 500 kV cables (twelve to eighteen individual cables) could be required to provide the 4,200 MVA power transfer capacity that will be required for TrAIL. As I stated above, these multiple sets of cables, and required conduit and vaults, would be a significant contributing factor to the larger excavation that would be required along the selected right-of-way segment. Additionally, the electrical capacitance for underground transmission lines is significantly higher as compared to overhead lines.

Q. WOULD YOU BRIEFLY EXPLAIN CAPACITANCE AND WHY IT IS SIGNIFICANT TO THE ISSUE OF UNDERGROUND TRANSMISSION LINES?

A. Yes. Cable capacitance is an inherent property of all cable systems, and results from the placing of insulation material between two cylindrical electrodes – the internal cable conductor and outer cable shielding. Capacitance may cause a significant increase in steady-state voltages throughout a power system as the charging current – the amount of current required to charge and discharge the cable capacitance at a frequency of 60 times per second – flows through inductive impedances such as transformers. Even without the presence of these transformers, a phenomenon known as the "Ferranti effect" causes voltage increases when the cable charging current flows through the power system itself. The flow of charging current generates heat, reducing the amount of through-current the cable is capable of carrying. This means that the charging current required for 500 kV underground cables would consume the entire power transfer capabilities of any cables greater than sixty miles in length (depending upon the type of cable), rendering the cables useless. Finally, the cable capacitance challenges I just described could also cause unacceptably high transient over-voltage conditions on substation equipment during switching operations, damaging the equipment and possibly causing costly, long-term outages.

Q. DO UNDERGROUND TRANSMISSION LINES PRESENT ANY RELIABILITY DISADVANTAGES?

A. Yes. A significant example is simply the additional time required for unforeseen events and repairs to an underground facility as compared to overhead lines. A problem on a 500 kV line placed underground could require as long as a month or more to locate and repair; such emergencies on an overhead facility can be located and repaired much more quickly. Repairing a cable failure typically involves bringing heavy construction equipment to the site (perhaps requiring placing temporary construction roads to move the equipment so the failure location can be accessed). If an entire manhole-to-manhole section of XLPE cable is replaced, a cable reel weighing 60,000 pounds or more must be brought to the site, the damaged cable removed, new cable installed, and a new splice made at either end. If a HPFF cable fails, the situation is much worse since large excavations would be required adjacent to the failure to freeze the dielectric liquid before the pipe can be cut open and repairs made. There is no experience with 500-kV polyethylene-insulated cables in the duct-and-manhole system used by U.S. utilities, and no experience with 500-kV fluid-filled cables whatsoever. Researchers have expressed concern that there could be a common failure mode such as thermo-mechanical movement that could result in multiple outages on these systems. Prolonged outages of the longer durations that could be experienced with an underground facility would be counterproductive to PJM's designation of the TrAIL project as a transmission expansion necessary to maintain grid reliability.

Q. ARE THERE CABLES AVAILABLE TO THE ELECTRIC INDUSTRY THAT COULD BE PLACED UNDERGROUND AT THE VOLTAGE LEVEL AND LENGTH PLANNED FOR TRAIL?

A. Three cable types could be considered; again, however, none have been installed at 500 kV beyond the limited lengths of the installations I described above. The three possible cable types would be (i) high-pressure fluid-filled ("HPFF") cables; (ii) extruded dielectric, cross-linked polyethylene ("XLPE") cables; and, (iii) self-contained fluid-filled ("SCFF") cables. For installation at 500 kV, however, the HPFF or the XLPE cables would be the most likely candidates. Both types, however, would present significant construction and operational issues that would be disadvantageous. SCFF cables are seldom used for installations on land; they are primarily installed on long alternating current submarine crossings.

Q. PLEASE DESCRIBE HPFF CABLES AND ISSUES THIS CABLE TYPE WOULD PRESENT.

A. HPFF cable accounts for most of the limited amount of underground 345 kV transmission facilities currently in commercial service in the United States, the longest of which is a seventeen-mile line. Industry-sponsored tests in this country have demonstrated the technical feasibility of these cables in a 500 kV application, but there have been no commercial installations of HPFF cables in the United States at this higher voltage. A previous short, trial installation of HPFF at 500 kV in Japan is not currently in commercial service. HPFF conductors are insulated with wrapped layers of a laminated paper/plastic tape that are factory impregnated with a dielectric liquid and shipped to the installation site on large reels. The three separate phases are then pulled at one time into a previously installed 8.625-inch (for 345 kV cables) outside diameter, coated and cathodically-protected steel pipe. 500 kV cables would probably require at least a 10.75-inch outside diameter pipe. The line is filled with a dielectric liquid that is pressurized to 200-250 pounds per square inch gauge ("psig"). At a minimum, a large pressurizing plant is installed at each end of the line segment to maintain this pressure while accepting fluid expansion and contraction. Assuming level terrain along the right-of-way, a pressurizing plant is installed at each end of the underground line segment to maintain pressure while accepting fluid expansion and contractions. For a right-of-way with significant terrain changes such as the preferred route for TrAIL, however, an HPFF cable system would also be segregated into multiple hydraulic (pressurizing) sections wherever elevation changes of greater than 300 feet occur along the right-of-way. The large volumes of dielectric fluids in the cable pipe (approximately 100,000 gallons for each line of a four to six line installation of a ten-mile segment) presents the potential for a large release of this fluid into the environment in the event of a major leak on even one of the cables. The entire 100,000 gallons of fluid could leak from the pipe, in the hypothetical ten-mile segment described above, depending upon the location of a leak and the time required for utility crews to find and reach that location to plug the leak. HPFF cables present the issues of reduced power transfer capability, higher electrical capacitance, and high transient over-voltages I mentioned above, and are susceptible to outages for both hydraulic and electrical problems. Finally, the installation of HPFF cables requires special training and, while there are foreign suppliers, there is only one domestic supplier for these cables, and none of these foreign or domestic suppliers have ever manufactured commercially-feasible lengths of 500 kV cables.

Q. LIKEWISE, WOULD YOU PLEASE DESCRIBE XLPE CABLE AND IDENTIFY ANY ISSUES THE POSSIBLE USE OF THIS TYPE OF CABLE WOULD PRESENT?

A. XLPE cables are conductors insulated with polyethylene, which is extruded over the conductors and then cross-linked at high temperatures. A lead, aluminum, or copper sheath is applied, and the individual conductors are configured as three XLPE-insulated cables that are pulled into individual plastic ducts in a concrete-encased duct bank or tunnel. There are only short, splice-free 345-kV XLPE lines in commercial service in this country for longer than a year (a 2.1 mile long circuit with splices was energized in 2007), but there are significant lengths totaling more than 100 miles installed at 330-kV and higher voltages including 500 kV overseas.

There are lengths totaling more than 150 miles installed at 230 kV in the United States, as well. However, no XLPE cable has been installed at 500 kV in the United States and the limited experience elsewhere has been in utility tunnels and not in an underground installation. The manufacture and installation of XLPE cable requires extremely high levels of quality control due to the high sensitivity of dielectric materials to contaminants and voids. XLPE cables above 230 kV are available only from foreign suppliers and these cables also require special skills and equipment for splicing during installation or for repairs. The lack of domestic suppliers and the special skill requirements, while not necessarily prohibitive to the initial installation of an underground facility, are factors that can contribute to the relatively longer duration of outage repairs on underground cables if replacement cables must be shipped from overseas locations and the necessary skilled labor must be located and brought to the outage site.

Q. PLEASE DESCRIBE THE CONFIGURATION OF FACILITIES THAT WOULD BE REQUIRED TO PLACE EVEN A SEGMENT OF TRAIL UNDERGROUND.

A. First, a dead-end type transmission structure would be required at each end of an underground line segment. Transition stations would also be required at each end of the underground segment; one station to transition the overhead facility into underground and the other station to transition back to an overhead facility. The transition stations would be fenced areas, much like a traditional substation, with dimensions of approximately 160 by 320 feet. Each station would have three cable terminations for each line – 12 to 18 terminations in total, each ten or so feet tall, on substation-type structures with bases ten feet or more above the ground. Flexible conductors would be required to drop down from the overhead conductors to the cable terminations. Additional equipment within each transition station would include switches, surge arrestors, equipment for communicating with transmission control rooms, including relaying and alarms, and any circuit breakers determined to be necessary. This would be repeated at each end of each segment of the line to be placed underground. For HPPF cable systems, pressurizing plants with pumps, controls, alarms, and a large storage tank would be required at each end of an underground segment.

Q. YOU INDICATED ABOVE THAT THE CABLES REQUIRE SPECIAL SPLICING. WOULD YOU PLEASE PROVIDE SOME ADDITIONAL DETAIL ABOUT THIS PROCESS?

A. Yes. The individual cables would be provided in lengths of no more than approximately 1,500 feet for XLPE-insulated cables, and perhaps 2,000 feet for HPFF cables, on large reels that may weigh as much as 60,000 pounds or even more. Consequently, splicing by factory or factory-trained splicing crews is a significant component of the construction of an underground transmission line.

This splicing process requires a “clean room” environment and can take up to ten days for each individual splice. Because between four and six three-conductor lines would be required, this would mean between 12 and 18 splicing procedures would be necessary for every fifteen hundred foot length of the planned underground segment and would require the cement vaults I described earlier. Mr. Lewis referred to these vaults as manholes and estimated that the West Virginia segment of TrAIL placed underground would require 405 of these underground structures. This complex process not only adds significantly to the length of time for constructing underground facilities, and as mentioned earlier it is a principal contributing factor to the relatively long outage periods that would result during an unforeseen event on an underground line segment. As a comparison, bare overhead transmission conductors are typically shipped in reel lengths of between 16,000 to 30,000 feet, depending on the size of conductor, and an overhead conductor splice typically takes one worker less than an hour to complete.

Q. REGARDING MR. HILDEBRAND'S TESTIMONY, DO YOU BELIEVE THAT SUPERCONDUCTING CABLES WOULD BE SUITABLE FOR TRAIL?

A. No. Although SuperPower and others have installed short lengths of superconducting cables as demonstration projects, there is no experience with cables anywhere near the length, voltage, and power transfer requirements of TrAIL. It will be many years before utilities even consider superconducting cables at lower transmission voltages as a commercial product suitable for integrating into the utility's transmission system.

Q. WOULD YOU PLEASE SUMMARIZE WHY, IN YOUR PROFESSIONAL OPINION, IT WOULD BE INFEASIBLE TO PLACE ANY PORTION OF THE TRAIL PROJECT UNDERGROUND?

A. I indicated at the start of my rebuttal testimony that, while it may be technically possible to place segments of TrAIL underground, the significant construction and operational challenges I have detailed above, in my opinion, make the placement of any portion of TrAIL underground infeasible. The significantly longer time periods that would be required to respond to unforeseen outages on an underground segment would largely, if not completely, negate TrAIL's intended purpose for transmission grid reinforcement and reliability enhancement. Because there is no commercial service experience with HPFF cables at voltage levels of 500 kV or with XLPE cables in an underground environment such as for TrAIL, any segment of the line placed underground would, for all intents and purposes, be the equivalent of a research and development demonstration project for the commercial feasibility of 500 kV underground transmission facilities. In my professional opinion, such an outcome would be particularly imprudent for a new high-voltage transmission facility that is intended to maintain transmission grid reliability.

Q. DO YOU ALSO AGREE WITH MR. LEWIS' CONCLUSIONS REGARDING THE CONSTRUCTION OF TRAIL AS A DC TRANSMISSION LINE?

A. Yes, I do. Mr. Lewis notes that many of the same concerns that are posed by the construction of TrAIL as an underground alternating current ("AC") facility remain if TrAIL were to be placed underground as a DC line. I agree with his assessment that the necessary conversion stations to accommodate AC/DC interconnections are costlier to construct and maintain and that, for both overhead and underground applications, these conversion stations have not demonstrated the same level of reliability as continuous AC circuits.

Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes, it does.