

TrAILCo Rebuttal Statement No. 15
Witness: Jay Williams

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

IN RE: APPLICATION OF TRANS-ALLEGHENY	:	
INTERSTATE LINE COMPANY FOR	:	
(I) A CERTIFICATE OF PUBLIC CONVENIENCE	:	
TO OFFER, RENDER, FURNISH AND/OR	:	
SUPPLY TRANSMISSION SERVICE IN THE	:	
COMMONWEALTH OF PENNSYLVANIA;	:	
(II) AUTHORIZATION AND CERTIFICATION	:	
TO LOCATE, CONSTRUCT, OPERATE AND	:	Docket Nos. A-110172
MAINTAIN CERTAIN HIGH VOLTAGE ELECTRIC	:	A-110172F0002
TRANSMISSION LINES AND RELATED ELECTRIC	:	A-110172F0003
SUBSTATION FACILITIES; (III) AUTHORITY	:	A-110172F0004
TO EXERCISE THE POWER OF EMINENT	:	G-000721229
DOMAIN FOR THE CONSTRUCTION AND	:	
INSTALLATION OF AERIAL ELECTRIC	:	
TRANSMISSION FACILITIES ALONG THE	:	
PROPOSED TRANSMISSION LINE ROUTES	:	
IN PENNSYLVANIA; (IV) APPROVAL OF AN	:	
EXEMPTION FROM MUNICIPAL ZONING	:	
REGULATION WITH RESPECT TO THE	:	
CONSTRUCTION OF BUILDINGS; AND	:	
(V) APPROVAL OF CERTAIN RELATED	:	
AFFILIATED INTEREST ARRANGEMENTS	:	

REBUTTAL TESTIMONY OF
JAY WILLIAMS

Re: Feasibility of Placing TrAIL Underground

December 10, 2007

REBUTTAL TESTIMONY OF JAY WILLIAMS

1 Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

2 A. My name is Jay Williams and my business address is 28 Lundy Lane, Ballston
3 Lake, New York 12019.

4

5 Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

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

12

13 Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS
14 PROCEEDING ON BEHALF OF THE TRANS-ALLEGHENY INTERSTATE
15 LINE COMPANY (“TrAILCo”)?

16 A. No, I have not.

17

18 Q. PLEASE DESCRIBE YOUR EDUCATIONAL BACKGROUND AND
19 PROFESSIONAL EXPERIENCE.

20 A. I earned a Bachelor of Science degree in engineering from Brown University and
21 an MBA from New York University. I worked as a cable engineer at
22 Consolidated Edison Company of New York, Inc. (“Con Edison”) from 1965

1 until 1973, and was in charge of the transmission cable group when Con Edison
2 was installing major amounts of 345-kV cable. I worked at Power Technologies,
3 Inc. from 1973 until 1992 and was in charge of the cable group when I left in
4 1992 to form PDC with another cable specialist. At PDC, I head a group of
5 engineering professionals, including five engineers whose entire collective
6 workload is spent on transmission cable systems. I have developed and present
7 several courses each year on underground power transmission, and have written
8 more than fifty technical papers, articles, and book sections on underground
9 transmission cables. I am a Fellow of the Institute of Electrical and Electronics
10 Engineers, Inc. ("IEEE") and a registered Professional Engineer in New York and
11 Ohio. My resume is attached to this testimony as TrAILCo Rebuttal Exhibit JW-
12 1.

13
14 **Q. HAVE YOU PREVIOUSLY APPEARED AS A WITNESS BEFORE ANY**
15 **REGULATORY AGENCIES?**

16 **A. Yes. I testified as an expert witness on behalf of the Vermont Department of**
17 **Public Service for the cable crossing at Grand Isle as part of the PV-20 line**
18 **application and regarding an application by the Vermont Electric Power**
19 **Company, Inc. and Green Mountain Power Company for authority to construct**
20 **the Northwest Vermont Reliability Project. I have also testified as a cable expert**
21 **for several utilities evaluating underground transmission lines. I am currently**
22 **assisting Northeast Utilities as their expert witness on cable systems for major 345**

1 kilovolt ("kV") installations as part of the Southwest Connecticut Reliability
2 Project.

3

4 Q. WILL THE USE OF VARIOUS TERMS IN YOUR REBUTTAL TESTIMONY
5 BE CONSISTENT WITH THE DEFINITIONS ASSIGNED TO THOSE TERMS
6 IN THE TABLE OF NOMENCLATURE ATTACHED TO TrAILCo WITNESS
7 FLITMAN'S DIRECT TESTIMONY AS TrAILCo EXHIBIT DEF-1?

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

9

10 Q. PLEASE DESCRIBE THE TOPIC AND PURPOSE FOR YOUR REBUTTAL
11 TESTIMONY.

12 A. My rebuttal testimony will address and respond to the various suggestions or
13 comments that were offered during the public input hearings in Pennsylvania
14 regarding whether the proposed TrAIL project or any portion thereof can be
15 placed underground.

16

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

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

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

4 A. There are no current examples of the installation of 500 kV cables of any
5 appreciable length in the United States and certainly none at the length of the
6 route proposed for TrAIL. In fact, the only instance of cables of this voltage
7 being placed underground of which I am aware in this country is a short length
8 less than two miles long of 500 kV underground cables that were installed within
9 the property of Grand Coulee Dam in the 1970s, from the generator transformers
10 to a switchyard. Following a catastrophic failure and fire soon after installation,
11 the replacement cables have operated satisfactorily. During that same period, a
12 500 kV gas-insulated line a few hundred feet long was installed on the West
13 Coast, but it has since been abandoned. Outside of the United States, 500 kV
14 cables have been installed underground on a limited basis in utility tunnels or
15 under bridges for lengths of less than twenty five miles in Japan and Canada. In
16 addition, 500 kV submarine cables of lengths limited to about 25 miles or less
17 have been installed between Vancouver, British Columbia and Vancouver Island.

18

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

21 A. Beginning with construction-related disadvantages, placing electric cables
22 underground requires a massive excavation of the entire length of the segments of
23 right-of-way planned for underground installation, as compared to excavating

1 material only at tower locations for an overhead line. To accommodate a 500 kV
2 project with the power transfer capacity required of TrAIL, such an excavation
3 would be particularly large in width. For example, as I explain below in my
4 rebuttal testimony, several sets of cables would be required to provide the power
5 transfer capability of the three-phase overhead circuit planned for TrAIL. These
6 cables would be spliced together in fifteen hundred foot sections and would be
7 placed into individual plastic conduits. Each set of cables could require cement
8 vaults approximately every fifteen hundred feet, at the points of splicing, that
9 would be approximately 35 feet long by 8 feet in width and height. The extensive
10 excavation required to place cables underground could also severely affect
11 streams, wetlands, and other environmentally sensitive areas along a proposed
12 right-of-way. Finally, as compared to a relatively limited number of access roads
13 that would be required for subsequent maintenance and repair operations along an
14 overhead right-of-way, permanent roads would be required along the entire
15 lengths of any underground segments for the line.

16
17 Q. ARE THERE DISADVANTAGES TO PLACING 500 KV CABLES
18 UNDERGROUND FROM AN ELECTRICAL AND OPERATIONAL
19 PERSPECTIVE?

20 A. Yes, there are several. Because they cannot dissipate heat as effectively as
21 conductors in an above-ground open air configuration, an underground cable is
22 able to carry far less power than a similarly-sized overhead line. Consequently,
23 perhaps as many as four to six sets of 500 kV cables (twelve to eighteen

1 individual cables) could be required to provide the power transfer capacity that
2 will be required for TrAIL. As I stated above, these multiple sets of cables, and
3 required conduit and vaults, would be a significant contributing factor to the
4 larger excavation that would be required along the selected right-of-way segment.
5 Additionally, the electrical capacitance for underground transmission lines is
6 significantly higher as compared to overhead lines.

7

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

11 A. Yes. Cable capacitance is an inherent property of all cable systems, and results
12 from the placing of insulation material between two cylindrical electrodes – the
13 internal cable conductor and outer cable shielding. Capacitance may cause a
14 significant increase in steady-state voltages throughout a power system as the
15 charging current – the amount of current required to charge and discharge the
16 cable capacitance at a frequency of 60 times per second – flows through inductive
17 impedances such as transformers. Even without the presence of these
18 transformers, a phenomenon known as the "Ferranti effect" causes voltage
19 increases when the cable charging current flows through the power system itself.
20 The flow of charging current generates heat, reducing the amount of through-
21 current the cable is capable of carrying. This means that the charging current
22 required for 500 kV underground cables would consume the entire power transfer
23 capabilities of the cables beyond segment lengths of sixty miles or less, depending

1 upon the type of cable. Finally, the cable capacitance challenges I just described
2 could also cause unacceptably high transient over-voltage conditions on
3 substation equipment during switching operations.

4

5 Q. DO UNDERGROUND TRANSMISSION LINES PRESENT ANY
6 RELIABILITY DISADVANTAGES?

7 A. Yes. A significant example is simply the additional time required for unforeseen
8 events and repairs to an underground facility as compared to overhead lines. A
9 problem on a 500 kV line placed underground could require as long as a month or
10 more to locate and repair; such emergencies on an overhead facility can be
11 located and repaired much more quickly. There is no experience with 500-kV
12 polyethylene-insulated cables in the duct-and-manhole system used by U.S.
13 utilities, and no experience with 500-kV fluid-filled cables whatsoever.
14 Researchers have expressed concern that there could be a common failure mode
15 such as thermo-mechanical movement that could result in multiple outages on
16 these systems. Prolonged outages of the longer durations that could be
17 experienced with an underground facility would be counterproductive to PJM's
18 designation of the TrAIL project as a transmission expansion necessary to
19 maintain grid reliability.

20

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

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

10

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

13 A. HPFF cable accounts for most of the limited amount of underground 345 kV
14 transmission facilities currently in commercial service in the United States, the
15 longest of which is a seventeen mile line. Industry-sponsored tests in this country
16 have demonstrated the technical feasibility of these cables in a 500 kV
17 application, but there have been no commercial installations of HPFF cables in
18 the United States at this higher voltage. A previous short, trial installation of
19 HPFF at 500 kV in Japan is not currently in commercial service. HPFF
20 conductors are insulated with wrapped layers of a laminated paper/plastic tape
21 that are factory impregnated with a dielectric liquid and shipped to the installation
22 site on large reels. The three separate phases are then pulled at one time into a
23 previously installed 8.625-inch (for 345 kV cables) outside diameter, coated and

1 cathodically-protected steel pipe. 500 kV cables would probably require at least a
2 10.75 outside diameter pipe. The line is filled with a dielectric liquid that is
3 pressurized to 200-250 pounds per square inch gauge (“psig”). At a minimum, a
4 large pressurizing plant is installed at each end of the line segment to maintain
5 this pressure while accepting fluid expansion and contraction. Assuming level
6 terrain along the right-of-way, a pressurizing plant is installed at each end of the
7 underground line segment to maintain pressure while accepting fluid expansion
8 and contractions. For a right-of-way with significant terrain changes such as the
9 preferred route for TrAIL, however, an HPFF cable system would also be
10 segregated into multiple hydraulic (pressurizing) sections wherever elevation
11 changes of greater than 300 feet occur along the right-of-way. The large volumes
12 of dielectric fluids in the cable pipe (approximately 100,000 gallons for each line
13 of a four to six line installation of a ten-mile segment) presents the potential for a
14 large release of this fluid into the environment in the event of a major leak on
15 even one of the cables. The entire 100,000 gallons of fluid could leak from the
16 pipe, in the hypothetical ten-mile segment described above, depending upon the
17 location of a leak and the time required for utility crews to find and reach that
18 location to plug the leak. HPFF cables present the issues of reduced power
19 transfer capability, higher electrical capacitance, and high transient over-voltages
20 I mentioned above, and are susceptible to outages for both hydraulic and electrical
21 problems. Finally, the installation of HPFF cables requires special training and,
22 while there are foreign suppliers, there is only one domestic supplier for these

1 cables, and none of these foreign or domestic suppliers have ever manufactured
2 commercially-feasible lengths of 500 kV cables.

3

4 Q. LIKewise, would you please describe XLPE cable and
5 identify any issues the possible use of this type of cable
6 would present?

7 A. XLPE cables are conductors insulated with polyethylene, which is extruded over
8 the conductors and then cross-linked at high temperatures. A lead, aluminum, or
9 copper sheath is applied, and the individual conductors are configured as three
10 XLPE-insulated cables that are pulled into individual plastic ducts in a concrete-
11 encased duct bank or tunnel. There are only short, splice-free 345-kV XLPE lines
12 in commercial service in this country for longer than a year (a 2.1 mile long
13 circuit with splices that was energized in 2007), but there are significant lengths
14 totaling more than 100 miles installed at 330-kV and higher voltages including
15 500 kV overseas. There are lengths totaling more than 150 miles installed at 230
16 kV in the United States, as well.

17

18 However, no XLPE cable has been installed at 500 kV in the United States and
19 the limited experience elsewhere has been in utility tunnels and not in an
20 underground installation. The manufacture and installation of XLPE cable
21 requires extremely high levels of quality control due to the high sensitivity of
22 dielectric materials to contaminants and voids. XLPE cables above 230 kV are
23 available only from foreign suppliers and these cables also require special skills

1 and equipment for splicing during installation or for repairs. The lack of domestic
2 suppliers and the special skill requirements, while not necessarily prohibitive to
3 the initial installation of an underground facility, are factors that can contribute to
4 the relatively longer duration of outage repairs on underground cables if
5 replacement cables must be shipped from overseas locations and the necessary
6 skilled labor must be located and brought to the outage site.

7

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

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

1 segment of the line to be placed underground. For HPPF cable systems,
2 pressurizing plants with pumps, controls, alarms, and a large storage tank would
3 be required at each end of an underground segment.

4

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

8 A. Yes. The individual cables would be provided in lengths of no more than
9 approximately 1,500 feet for XLPE-insulated cables, and perhaps 2,000 feet for
10 HPPF cables, on large reels that may weigh as much as 60,000 pounds or more.
11 Consequently, splicing by factory or factory-trained splicing crews is a significant
12 component of the construction of an underground transmission line. This splicing
13 process requires a “clean room” environment and can take up to ten days for each
14 individual splice. Because between four and six three-conductor lines would be
15 required, this would mean between 12 and 18 splicing procedures would be
16 necessary for every fifteen hundred foot length of the planned underground
17 segment and would require the cement vaults I described earlier. This complex
18 process not only adds significantly to the length of time for constructing
19 underground facilities, it is the principal contributing factor to the relatively long
20 outage periods that would result during an unforeseen event on an underground
21 line segment. As a comparison, bare overhead transmission conductors are
22 typically shipped in reel lengths of between 16,000 to 30,000 feet, depending on

1 the size of conductor, and an overhead conductor splice typically takes one
2 worker less than an hour to complete.

3

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

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

1 Q. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

2 A. Yes. I reserve the right, however, to file such additional testimony as may

3 become necessary or appropriate.

JAY A. WILLIAMS - PRINCIPAL ENGINEER

Jay A. Williams received a BS in Engineering from Brown University in 1965 and a Master of Business Administration from New York University in 1972. He joined the Consolidated Edison Company of New York in 1965, and held engineering positions in several groups at Con Edison until he joined Power Technologies, Inc. in 1973. He served in the U.S. Air Force, Base Civil Engineers, in the 1960's. He and John Cooper founded Power Delivery Consultants, Inc in 1992.

As a Senior Engineer in charge of Con Edison's Transmission Cable Group, Mr. Williams' responsibilities included system design and preparation of specifications for 138-kV and 345-kV underground transmission lines and accessory equipment; economic studies of proposed underground transmission systems; field supervision for nonstandard construction operations; and fault analysis and repair. He had responsibility for detailed design of cable bays for the Waltz Mill Cable Test Facility. He was Project Engineer for installation of the world's first underground 345-kV SF₆ - insulated transmission line, and supervised the construction of the line in 1971.

After joining PTI, Mr. Williams was responsible for experimental projects for the forced cooling of high-pressure, fluid-filled cable circuits. These projects were the first ones to undertake the installation, instrumentation, and analysis of a full-scale cable system. He was also project engineer for an EPRI-sponsored study to develop rapid and accurate leak location systems for buried cables.

Mr. Williams has conducted technical and economic studies of alternate underground systems, for voltages from 138 kV to 500 kV ac, as well as HVDC. He has prepared testimony and represented utilities and commissions in hearings. He designed and supervised the construction of an extensive uprating project for existing pipe-type cables, and has been responsible for engineering analysis, specifications, bid review, and field supervision for many underground and submarine cable projects for both utilities and architect-engineers.

In addition to utility design/installation projects, he was project engineer for the EPRI – funded development of the ACE program to perform technical and economic analyses of cable systems. He was in charge of the EPRI project to prepare the 1992 edition of the Underground Transmission Systems Reference Book; he wrote the Cable Ampacity chapter plus several other chapters of the book. He was also project engineer for the EPRI Underground Transmission Workstation project, as well as several other EPRI-funded projects — including the Distributed Fiber Optic Temperature Monitoring development. He has taught many courses and seminars for underground transmission cables, from system planning to field operation & maintenance.

Mr. Williams is a Fellow of the IEEE, and member of the Power Engineering Society and Electrical Insulation Society. He is a Voting Member of the IEEE Insulated Conductors Committee and served as Chairman of the Insulations Subcommittee. Mr. Williams has authored more than fifty technical articles and papers, and was co-author of the Underground Transmission Systems section of the McGraw-Hill Standard Handbook for Electrical Engineers. He is a registered Professional Engineer in the States of New York and Ohio.