PPL ELECTRIC UTILITIES

TRANSMISSION LINE DESIGN CRITERIA

FOR PJM "OPTION TO BUILD" FACILITIES TO BE OWNED AND OPERATED BY PPL ELECTRIC UTILITIES

(ANY "OPTION TO BUILD" PROPOSAL MUST BE REVIEWED AND APPROVED BY PPL TRANSMISSION STANDARDS AND ENGINEERING PRIOR TO START OF CONSTRUCTION)

Version 0

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Introduction

Because of the steadily growing use of electricity, new generating facilities and transmission lines are required to meet that demand and maintain a reliable power system. PJM Interconnection, the independent company that operates the electric power grid for a 13-state region which includes Pennsylvania, has allowed third party Developers to design and build facilities to support the development and expansion of the transmission grid.

With respect to the design and construction of transmission line facilities, PJM has developed and posted on the PJM web site a number of generic design requirements associated with the "Option to Build." This document, however, states specific transmission line design criteria that a Developer must follow in order to meet basic PPL EU specific design requirements. These generic requirements have been developed over the years and incorporating past actual experience during the operation of transmission lines in the PPL EU Pennsylvania service territory. When a Developer chooses the "Option to Build" for transmission facilities, they must understand that they are required to follow both the PJM and / or the PPL EU transmission line design criteria. These transmission line design criteria are being prepared in order to ensure that all future transmission lines that tie into the existing grid will be reliable and high performing and reduce the probability that operation of these facilities will adversely affect the transmission grid and interconnected customers

In general, the Developer or their Transmission Engineering Contractor is responsible to perform a complete engineering design protocol including, but not limited to:

- The acquiring of transmission line rights-of-way covering the line from the IPP's point of interconnection to PPL EU's tie in structure.
- Acquiring a field survey, soil borings and Geo-Tech report necessary to perform an accurate design.
- Support drawing preparation and design narrative, as necessary, for PPL EU's siting application with the Pennsylvania Public Utility Commission (PPUC).
- Perform field analysis/collection of environmental data, preparation, filing and acquisition of all necessary permits and approvals (environmental, cultural, foreign utility, railroad, river crossing, municipal, state, federal, etc.) to support the proposed construction schedule.
- Preparation of a complete design and construct package with necessary modeling, drawing preparation, bill of materials, etc.
- Preparation and coordination of the complete bid and order process for steel poles including foundation designs.
- Preparation of construction bid packages and facilitation of pre-bid meetings.
- Engineering response to any construction issues and final as-built requirements.

Scope

The criteria included in this document along with the basic PJM "Option to Build" standards are to be used by the Developer for the safe and reliable design of any non-utility "Option to Build" transmission lines in PPL EU (PPL) service territory. If there are any questions regarding design criteria the developer should contact PPL to discuss the issue prior to making an assumption and proceeding with the design.

Summary of Major Design References

ANSI C2-2012 National Electric Safety Code (NESC), 2012 Edition

ASCE/SEI Standard 48-05, Design of Steel Transmission Pole Structures, 2006 Edition

ASCE Manual No. 74, Guidelines for Electrical Transmission Line Structural Loading, 2010 Third Edition.

PJM Design of Overhead Transmission Lines, TSDS Technical Requirements, Section V.A., Pages 1 thru 12, dated 5/20/2002.

PPL Safety Rule Book, Section 8, “Working Near or On Electrical Facilities,” dated 06/2012

PPL Specification for Soil Erosion and Sedimentation Control on Transmission Rights of Way A-118231 Rev 5 10/31/1996

PPL Concrete Materials & Placement Specifications A-190975 Rev 1 9/12/2007

PPL Concrete Materials Specification A-190974 Rev 2 10/16/2007

PPL Fiber Optic Overhead Ground Wire Specification

PPL Fiber Optic Overhead Ground Wire Splicing Specification

PPL Right of Way Manual with Sample Agreements

PPL Right of Way Clearing Specification LA-79827 December, 1993

PPL Transmission Construction Specifications,
Section 29 Overhead General Information
Section 30 Poles, Arms, and Guys
Section 32 Grounding and Counterpoise
Section 33 Overhead Sectionalizing
Section 36 Steel Poles – 69kV Structural Details
Section 39 Steel Poles 69 – 230kV Instructions
Section 40 Steel Poles – 138kV Structural Details
Section 42 Steel Poles – 230kV Structural Details
Section 44 Steel Poles – 500kV Instructions
Section 46 Steel Poles – 500kV Structural Details
Section 47 Conductor Information 500kV
Section 49 Fiber Optic Cable Attachments - Transmission

PPL Specification for Fabricated Steel Poles, LA-50181, 12/31/2007 General Revision (Note: This Document is in the process of being revised)

Recommended Practices for Helicopter Bonding Procedures for Live-Line Work, IEEE Transactions on Power Delivery, Volume 15, Issue No. 1, January, 2000

Transmission Line Reference Book-Wind Induced Conductor Motion, Electric Power Research Institute, 1979

1. Developer Project Deliverables

1.1. Perform any field surveys to acquire topography and other field data, as necessary, for project design. Provide all electronic copies of the associated AISC survey files to PPL EU. Developer shall be responsible for the staking of all proposed locations for core borings, Right of Way (R/W) acquisition and any other associated engineering activity such as wetland delineation.

1.2. Apply for and receive a Design PA-1 Call response. List all design one call serial numbers with description of limits on the final Plan and Profile submitted for construction.

1.2.1. Perform subsurface utility analysis to address construction access and external loading limits for all foreign utility crossings.

1.2.2. Develop design solutions and obtain crossing approvals for all foreign utility crossings from other owner utilities.

1.3. Review to determine whether any Federal Aviation Administration or Pennsylvania Department of Transportation - Bureau of Aviation regulations apply, provide written notification to those agencies for their review and acceptance, incorporate any requirements in the design and note any specific construction details on the new drawing set. Aviation marker spheres shall be made a part of the construction requirements on all prominent crossings, such as limited access highways, river or major ravines. Any aviation marker lights that are required must have an automatic monitoring system installed with each light.

1.4. Acquire transmission line right-of-way covering the line from the IPP's point of interconnection to PPL EU's tie in structure. Prepare associated right of way drawings for the acquisition of property rights for the project. By exception, the Developer may be requested to obtain property abstracts (100 year history). Right of way manual with sample agreement will be provided on request. Right of way clearing will be per PPL specification LA79827.

1.5. Acquire all necessary environmental permits such as erosion & sedimentation control, wetlands encroachments, stream/river and other utility crossings, etc. The Developer shall determine and define who, if any other, third party sub-contractor will be utilized for permitting. The design goal shall be to minimize impacts to reduce permitting requirements.

1.6. Support the filing and acquisition of PPUC Certification approval as required by PPL EU and PPL Office of General Counsel (typically involves the preparation of design parameters including calculation of EMF levels for specific operating criteria, compiling a design narrative for the filing and personally providing professional design testimony at public meetings, hearings, etc.). A sample of siting application design information can be supplied at the start of the project.

1.7. Prepare a project One Line Diagram.

1.8. Prepare all required drawings to obtain all necessary permits and approvals (foreign utility, river and railroad crossings, governmental (local, state, federal) agencies, etc.).

1.9. PPL EU recommends preparing the line design utilizing PLS-CADD, method #4 or latest equivalent full finite element analysis software. A copy of the final PLS-CADD design file shall be provided electronically to PPL EU.

1.10. Prepare a complete set of design/construction drawings. The required contents of same are noted below in this document. One preliminary hard copy of same labeled Revision "A" shall be submitted for comment; redline markup and/or concurrence by PPL EU at least one month before the scheduled engineering complete date. One final PLS-CADD electronic file and one revised hard copy drawing set, revision 0, for internal issue shall be submitted to PPL EU no later than three days before the scheduled engineering complete date.

1.11. The Developer is responsible for QA/QC during both the preliminary and the final design to assure that all final changes were made based on the PPL EU design review.

1.12. All final drawings shall be approved and sealed by a registered professional engineer certified within the Commonwealth of Pennsylvania.

1.13. Prepare a steel pole bid and order package including Steel Pole Loading Summaries, Pole Outline Drawings, Pole Bill of Material, and associated relevant guying details, diagrams, etc. A sample of the bid/order and processing packages can be supplied at start of design engineering. The package prepared for the specific project may utilize different formats with different content than shown on the sample. One electronic and one hard copy of all of the bid and order information, noted above, shall be submitted to PPL EU.

1.14. Perform a review and approval of each of the steel pole manufacturers' bidding design calculations to assure all loading requirements are satisfied. Any discrepancies must be resolved between the Developer and the steel pole vendor. It is highly recommended that the pole calculations be verified utilizing PLS POLE software.

1.15. Perform review and approval of the selected steel pole vendor's fabrication drawings including anchor bolt cluster details. Any changes/discrepancies must be resolved between the Developer and the steel pole vendor via redline markups and/or written documentation. The Developer is responsible to assure that the steel pole vendor has made all of the necessary corrections and submits a final electronic AutoCAD file of the entire drawing set. The Developer shall format the drawing set with PPL EU standard "C" size formats, sign off in the approval block and submit both a hard and electronic copy to PPL EU.

1.16. Stake and acquire a core boring and a Geo-Tech report for each structure site and perform a customized foundation design for each structure.

1.17. Developer shall determine and specify all of the associated hardware that will be required for the OPGW installation along with splice locations determined. The hardware specified must meet the wire manufacturer's specifications and utilize their recommended supplier.

1.18. Developer shall locate all proposed OPGW splice locations at easily accessible structures.

1.19. Developer shall provide a summary bill-of-material by individual structure to the designated PPL EU design representative.

1.20. Routinely provide progress and status updates via (1) conference calls with designated PPL representatives once every month, (2) by holding routine meetings on an as-needed basis or as requested by PPL EU and (3) with monthly reports submitted electronically with the following information:

- Updated Schedule
- Activities during prior month
- Planned activities for upcoming month
- Progress in meeting schedule
- Significant issues that may impact the scheduled completion of the project

1.21. Attend PPL EU meetings and/or field walk-downs upon request.

1.22. Perform a final field walk-down and/or pre-construction bid walk-down with designated PPL EU representatives and construction contractors.

1.23. Revise the final drawing set with any As-Built changes that surfaced during construction.

1.24. Developer shall support resolution of any inquiries, problems or issues that surface during actual construction.

1.25 Once the transmission facility is completely constructed and before the final “Acceptance of Facility” is approved that allows the line to be energized, PPL will require a third party helicopter contractor to perform an overhead comprehensive inspection to verify that all components are installed properly. This comprehensive overhead helicopter inspection is required at the Developers expense prior to PPL EU taking over ownership and maintenance responsibilities.

Note: PPL EU Transmission Engineering and T&S Standards will work closely with Developer to supply examples of various drawing formats, steel pole bid/order information, caisson foundation information, associated PA PUC information, etc.

2. Transmission Line Design Criteria

2.1 Structure Description

2.1.1 PPL’s standard transmission line design for 69 and 138 kV should include custom designed tubular steel poles that are direct embedded (i.e. short span tangent structures) and / or self-supported (i.e. long span and angle structures) steel mono poles with vertical phase conductor configuration. PPL’s standard transmission line design for all 230kV and 500kV must include custom tubular steel pole structures set on concrete caisson foundations. The typical 500 kV structure configurations used by PPL are attached as Appendix “B.” Typical 69 – 230kV structure configurations used by PPL are included in PPL Transmission Construction Specifications.

2.1.2 The new steel poles will be designed to allow for live line energized maintenance activities. Vertical spacing of phase conductors for 500kV lines will be large enough to permit helicopter-based maintenance of the line. Based on a review of the IEEE Paper, “Recommended Practices for Helicopter Bonding Procedures for Live-Line Work”, thirty-two feet of vertical clearance is required between phase conductors for this purpose on all 500kV designed lines. For 500kV and 230 kV multiple insulator strings shall be used for all dead end s tructures and f or all areas where significant strain can occur. As an example for 500kV lines, the designer should be aw are that the maximum design condition of 1.5 radial inches of ice results in a vertical load of 22.2 pounds per phase foot for triple bundle 1590 45/7 Lapwing conductor. Conductors used for 230kV lines should be single 1590 45/7 Lapwing conductor and for 138kV and 69kV lines either 556.5 24/7 Parakeet or 795 30/19 Mallard. Shield angle between the OHGW/OPGW and the top phase wire must be 15 degrees or less.

2.1.3 Conductor phasing at affected structures shall be determined on a project by project basis. PPL will provide phasing at line terminations.

2.1.4 Family of Structures: (Framing design will be supplied once the Developer and PPL EU determine which voltage level will be used to interconnect with the transmission grid)

The following is included as an example for 500kV designed lines:

- Double Circuit – Single pole tangent suspension structure, Spec. 6-46-076, for spans up to 700 ft. and angles up to 1°, concrete caisson foundation.
- Double Circuit – Three pole tangent suspension structure, Spec. 6-46-078, for spans greater than 700 ft. and angles up to 1°, concrete caisson foundations.
- Double Circuit – Three pole running angle structure, Spec. 6-46-080, for angles from 1° to 20°, concrete caisson foundations.
- Double Circuit – Three pole in-line dead-end or tension-change structure, Spec 6-46-082, guyed, concrete caisson foundations.
- Double Circuit – Two Pole heavy angle, dead-end structure for angles greater than 20°, Spec. 6-46-084, concrete caisson foundations.

2.1.5 Steel Pole Loading Trees

The Developer / Designer are responsible for providing the steel pole manufacturer(s) with factored load trees for all structures for all design cases.

2.1.6 Anchor Guys

Guying of tubular steel poles is not recommended. If guying is required the guys will utilize 3/8”, 1/2", 3/4” and / or 1” diameter or greater as required to support the specific structure loads. All guys must be extra high strength galvanized steel wire. Guys will be terminated to a minimum of 24” plate / disk anchors, 36” disk anchors or concrete piers as required for design guy loads.

Use of rock anchors is discouraged. If required rock anchors may be used with 3/8” and 1/2” high strength steel guys only. The only approved rock anchors have to be a (polyester resin) expandable epoxy type rock anchor. Due to shifting rock conditions found in PA and the previous use of standard expandable mechanical type rock anchors that experienced in-service failures the mechanical style rock anchors are no longer acceptable for use at PPL. If any rock anchor is used a pull test on the rock bolt anchor is required prior to the “Acceptance of Facility” is completed.

All guys shall be designed for the greater load condition of the following:

a.) “NESC Heavy” with overload capacity factors (OLCF) included and based on 65% of ultimate stress (minimum breaking stress), or

b.) Any other load condition governing guy design with loads reduced to OLCF of 1.0 (loads shown on designer’s summary divided by the appropriate OLCF) and based on 65% of ultimate guy stress.

2.2 Wire Data

2.2.1 Wire Data for 500kV

	Proposed Conductor (Triple Bundle)	**Shield Wire**	**OPGW**
Type	ACSR	Alumoweld	SFPOC
Code Name	Lapwing	N/A	SFSJ-J-5499
Size	1590 kcmil	19 #9	0.3271 in^2
Stranding	45/7	19	48 fiber
Diameter	1.504 in.	0.569 in.	0.752 in.
Weight per Foot	1.792 lbs.	0.569 lbs.	0.641 lbs.
Ultimate Strength	42,200 lbs.	34,290 lbs.	32,325 lbs.

2.2.2 Wire Data for 230kV

	Proposed Conductor	**Shield Wire**	**OPGW**
Type	ACSR	1/2” E.H.S. Steel	SFPOC
Code Name	Lapwing	N/A	SFSJ-J-5499
Size	1590 kcmil	7 strand	0.3271 in^2
Stranding	45/7	7 strand	48 fiber
Diameter	1.504 in.	0.495 in.	0.752 in.
Weight per Foot	1.792 lbs.	0.517 lbs.	0.641lbs.
Ultimate Strength	42,200 lbs.	26,900 lbs.	32,325 lbs.

Note: 1590 kcmil 54/19 Falcon could be required to support special long span requirements.

2.2.3 Wire Data for 138 / 69kV

	Proposed Conductor	Shield Wire	OPGW
Type	ACSR	3/8” H.S. Steel	SFPOC
Code Name	Parakeet	N/A	SFSJ-J-5288
Size	556.5 kcmil	7 strand	0.1713 in^2
Stranding	24/7	7 strand	48 fiber
Diameter	0.914 in.	0.360 in.	0.567 in.
Weight per Foot	0.7169 lbs.	0.273 lbs.	0.310 lbs.
Ultimate Strength	19,800 lbs.	10,800 lbs.	13,275 lbs.

Note: 795 kcmil 30/19 Mallard and / or 0.752” OPGW could be required to support special long span requirements.

Consideration will be given to equivalent diameter High Temperature Low Sag (HTLS) conductors and to alternate extra high strength OHGW’s / OPGW’s only if absolutely required to support extra-long spans at gorge and / or river crossings to reduce structure heights and / or to eliminate structures.

Conductors must be selected with sufficient thermal capability to meet continuous and emergency current ratings. Ratings of conductors applied to the PPL EU system should be determined using the PJM TSDS “Bare Overhead Transmission Conductor Ratings, November 2000”. The overhead line conductor and static wire will be chosen by PPL EU. This provides the ability to quickly repair a section of line with PPL EU stock material should an emergency arise. Standard PPL EU transmission conductor types are listed in Section 2.2 above. The ambient temperature range is listed in the Appendix for the PPL EU system and is used for the electrical ratings of the conductors as well as the structural loads upon the tubular steel structures.

2.3 Wire Tension Limits

The following tension limits will be applied for the calculation of structure loads:

Load Case	Conductor Tension Limits (% RBS)	Shield Wire / OPGW Tension Limits (% RBS)
1.5” ice, 0 wind, 0°F	50%	40%
NESC Heavy Loading, Initial	40%	28%
60^{o}F, Initial	22%	20%
60^{o}F, Final	18%	16%

2.3.1 Sagging

Shield wires shall be sagged to 70% - 80% of the final after-creep sag of the conductors at 60 degrees F.

2.3.2 Galloping

Single-loop galloping shall be assumed for spans less than 600 ft. Double-loop galloping shall be assumed for spans greater than 600 ft. A minimum clearance of 12” is required between wire galloping ellipses to minimize conductor or structure damage (double loop galloping). Long spans over 1800’ will take into account existing line historical operation and loop size reductions due to end connection (reference EPRI “Wind-induced Conductor Motion” page 156) and terrain.

The A.E. Davison method shall be used for modeling single loop galloping, and the L.W. Toye method shall be used for modeling double loop galloping. The conductor loading criteria to determine size of conductor motion ellipses is 1/2" ice, 32ºF with no wind, final sag; to determine shape of the ellipses use minor axis of 40% of major axis; to determine the sag and the displacement (swing) angle, use 1/2” ice, 32º F and a 2 psf wind, final sag.
Clearance between ellipses shall not be less than those shown below.

For spans equal to the ruling span length:	
Phase to Phase	1.0 ft
Phase to Shield Wire	1.0 ft
For spans of maximum span length:	
Phase to Phase	1.0 ft
Phase to Shield Wire	1.0 ft

2.3.3 Aeolian Vibration

Vibration analysis of the phase conductors and the OHGW / OPGW(s) will be performed using industry standard software such as Alcoa VIBRECO or acceptable equivalent. When required, dampers shall be properly installed on all phases and OHGW / OPGW(s) as indicated.

2.4 <u>Design Loading Criteria</u>

2.4.1 General

The transmission line shall be designed in accordance with the minimum loading requirements of NESC, Grade B construction, Heavy Loading district and PJM standards which mandate 1.5 inches radial ice, 0 winds at 0° F as maximum design loads for 230kV and above lines and 1.0 inch radial ice, 0 winds at 0 ºF as maximum design loads for lines below 230kV.

Loading Condition	Wire Wind Pressure	Pole Structure Wind Pressure (1)	Ice	Temperature (Tension Condition)
NESC Heavy Loading	4 psf	5.0 psf	1/2 "	0°F (Initial)
Extreme Wind	25 psf	25 psf	None	60°F (Initial)
NESC 250D	4 psf	5 psf	1.0"	15°F (initial)
Heavy Ice	0 psf	0 psf	1-1/2"	0°F (Initial)
Ice & Wind	8 psf	8 psf	1"	0°F (Initial)
Deflection: NESC Heavy Loading See note (2)	4 psf	5.0 psf	1/2 "	0°F (Initial)
Hot Conductor	0 psf	0 psf	None	284°F (Final)
Cold Conductor or S.W	0 psf	0 psf	None	-20°F (Initial)
Rake Condition See note (3)	0 psf	0 psf	None	60°F (Final)
Longitudinal Load – Suspension Structure				
Broken Wire- Any one conductor/sub conductor or shield wire	4 psf	5.0 psf	1/2 "	0°F (Initial)
Differential Ice loading	0 psf	0 psf	1" one side, no ice other side	32°F (Initial)
Stringing Load - Any one phase or shield wire	2 psf	2.5 psf	None	30°F (Initial)
Longitudinal Load – Strain Structure (Angle structure with line angle of 45 degrees or less)				
Broken Wire- Any one conductor/sub conductor or shield wire	4 psf	5.0 psf	1/2 "	0°F (Initial)
Longitudinal Load – Dead-end Structure				
All wires to be intact on one side only	4 psf	5.0 psf	1/2 "	0°F (Initial)

2.4.2 Overload Capacity Factors

2.4.2.1 Steel Structures - Grade B New Construction:

Loading Condition		Transverse			Longitudinal		Vertical	
	Wind on Conductor	Angle	Wind on Structure	Wind on Conductor	Angle	Wind on Structure	Weight of Conductor	Weight of Structure
NESC Heavy Loading	2.5	1.65	2.5	2.5	1.65	2.5	1.5	1.5
Extreme Wind	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
NESC 250D	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Ice & Wind	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Heavy Ice	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Deflection: NESC Heavy Loading	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Rake Condition	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Loading Condition		Transverse			Longitudinal		Vertical	
Broken Wire								
(3 or more conductors)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
(2 conductors)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
(1 conductor)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
All other Intact wires	2.5	1.65	2.5	2.5	1.65	2.5	1.5	1.5
Differential Ice	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Stringing								
(3 or more sub-conductors)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
(2 sub-conductors)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
(1 sub-conductor)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Footnotes:

1. Overload Capacity Factors must be included as part of each loading condition.
2. An additional 2 degree line angle shall be assumed on every structure, including tangents, to compensate for any necessary field adjustments during construction.
3. N.E.S.C. Class “B” Heavy Loading District applies on all projects. Per PJM requirements, for the purpose of calculating conductor or shield wire tensions, add 0.3 pounds to the resultant of the per linear foot weight, wind and ice loads. Allowable pole top deflection shall not exceed 5% of the overall pole length under this condition.
4. Selected anti-cascading dead-end structures shall have a distinct loading applied whereby all conductors and shield wires are broken on one side of the structure under all N.E.S.C. loading cases in addition to the broken wire loading condition above.
5. Any one phase conductor or shield wire at any given position on the structure is assumed broken. All other wires are intact. Longitudinal tensions shall not be reduced by assumed insulator swing on suspension framings. Selected anti-cascading dead end structures shall have a distinct loading applied whereby all conductors and shield wires are broken on one side of the structure.
6. Loads shall be applied at all conductor and shield wire positions with all wires sloping downward to puller/tensioners or temporary anchors. The horizontal and vertical components of the loads shall be derived at a 2:1 horizontal to vertical slope. Add 700 pounds for the weight of a person and tackle at the end of the arm. For the purpose of later maintenance, attachment points shall be provided on the arms above the conductors as a support point for the wires during line maintenance. To allow for simultaneous work on adjacent structures, these attachment points shall support twice the weight span of the wires with an additional 700 pounds for workmen and equipment at the end of the arms. Un-guyed, anti-cascading dead end structures must self-support all wires dead-ended on one side of the structure only with no temporary guying provided. When only a single circuit is installed initially on a double circuit framing the structure must support the associated torsional load with only one circuit dead-ended.
7. Supplemental loading for suspension insulator type structures only. Any one conductor or shield wire at any given position on the structure is assumed to bind in the stringing block during installation. Assume the block swings 45° in-line. The swing will result in a longitudinal/torsional load equal to the calculated vertical load under this condition on that specific wire.
8. All wires on one side of the structure shall have ice applied and all wires on the opposite side are bare. The calculated swing of suspension insulators and shield wire assemblies may be included to determine wire tensions.

9. Typically, pre-cambered poles are NOT recommended unless significant pole top deflections are encountered. Refer to PPL Steel Pole Fabrication Specification LA-50181, Design Item B – (d) concerning rake criteria. If significant pole top deflections occur, the best method for correction shall be determined (rake, pre-camber or increased design rigidity). Pole top deflection that is 1% or less of the overall pole length is acceptable without any adjustments. Rake adjustment up to 1/2 inch on the anchor bolt nuts is generally considered acceptable. Pole top deflections due to secondary moments, such as those created by an initial single circuit installed on a double circuit tangent framing, shall only be adjusted to 1/2 the deflection value in anticipation of counterbalance of the moments when the second circuit is installed at a later date. If deflection exceeds 18" steel poles will be pre-cambered. If deflection is 18" or less, pole will be raked to plumb condition.
10. A shape factor of 1.25 is assumed for wind in any direction on the structure. Allowable deflection in this case is 5% of pole height.

2.4.3 Stringing and Maintenance Loads

The following conditions have been assumed for developing the stringing and construction and maintenance design loads:

Stringing - Loads applied at all phases and shield wires with all wires sloping down to pullers, tensioners or temporary anchors. The horizontal and vertical components of this load are derived from the wires at a 2 horizontal to 1 vertical slope. Weight of a person(s) and tackle shall be included at 700 lbs.

Maintenance – Attachment points will be provided on the structure cross-arms directly above the phase conductors as a support point for the wires during line maintenance. To allow for simultaneous work on adjacent structures, these attachment points will be designed for twice the design weight span of the conductors with an additional load of 700 pounds for men and equipment on the cross-arms.

2.4.4 Longitudinal Unbalanced Loads

Tangent steel poles shall be designed for longitudinal unbalanced loads due to differential ice loading. Dead-end structures shall be designed for full terminal conditions under the NESC Heavy load case.

2.4.5 Uplift

The dead-end structures shall be designed to support an uplift load equal in magnitude but opposite in direction of the vertical load under NESC Heavy and Extreme wind design loading cases. Uplift shall be reviewed at -20°F for all conductors

2.4.6 Anchor Guys

Guying of tubular steel poles is not recommended. If guying is required the guys will utilize 3/8", 1/2", 3/4" and / or 1" diameter or greater as required to support the specific structure loads. All guys must be extra high strength galvanized steel wire. Guys will be terminated to a minimum of 24" plate / disk anchors, 36" disk anchors or concrete piers as required for design guy loads.

Use of rock anchors is discouraged. If required rock anchors may be used with 3/8” and 1/2” high strength steel guys only. The only approved rock anchors have to be a (polyester resin) expandable epoxy type rock anchor. Due to shifting rock conditions found in PA and the previous use of standard expandable mechanical type rock anchors that experienced in-service failures the mechanical style rock anchors are no longer acceptable for use at PPL. If any rock anchor is used a pull test on the rock bolt anchor is required prior to the acceptance of facility is completed.

All guys shall be designed for the greater load condition of the following:

a.) “NESC Heavy” with overload capacity factors (OLCF) included and based on 65% of ultimate stress (minimum breaking stress), or

b.) Any other load condition governing guy design with loads reduced to OLCF of 1.0 (loads shown on designer’s summary divided by the appropriate OLCF) and based on 65% of ultimate guy stress.

2.4.7 Span Ratio

In cases where a new structure is located in close proximity to an existing structure location the ratio of span lengths on either side of a suspension pole shall not exceed 3:2.

2.4.8 Anti-Cascading Loads

Tangent and strain structures will be designed for a single broken conductor or shield wire under NESC load conditions. Dead-end structures shall be designed for full terminal conditions under all design loading cases. Since every structure on the line will be designed for longitudinal load-carrying capability, the risk of cascading failures will be reduced.

2.5 Structure Finish

All new steel pole structures and associated attachments shall be weathering steel.

2.6 Clearances

The transmission line shall be designed for minimum clearances as specified by the more restrictive of PJM, NESC or PPL EU standards. To the extent permitted by the NESC, clearances will be based on using 2.2 per unit switching surges for 500kV lines and 2.0 per unit switching surges for 230kV lines, where this results in lesser clearances being required

2.6.1 Ground Clearances:

The transmission line shall be designed for the minimum ground clearances specified by NESC (Table 232-1) + 3 ft. or 53 ft. (500kV line), 32 ft. (230kV line) or 30 ft. (138/69kV line) whichever is greater, at a conductor temperature of 284°F (140°C.) The 3 ft adder is based on PJM requirements. See Appendix “A”. .

2.6.2 Wire Crossing Clearances:

The following table lists the vertical clearances required at crossing of other lines as specified in NESC Rules 233 and 235. The clearances include a construction tolerance of 3 ft. See Appendix “A”.

2.6.3 Clearances to Structure:

The following minimum clearances shall be maintained from the conductor to the supporting structure surface (NESC Tables 235-6 and 234-1). The clearances to grounded arms beneath conductors are shown below. Clearances to support arms or adjacent pole support shall be no less than 13 ft. See Appendix “A”.

2.6.4 Clearances to Edge of Right-of-Way

Horizontal clearance to the edge of the ROW shall be as follows:
To buildings and other supporting structures – as determined by NESC + 3 ft. margin

For 500kV lines:
6-psf wind at final sag – 17 ft.
No wind at final sag – 20 ft.
Air gap at structure – 13 ft. minimum

For 230kV lines:
6-psf wind at final sag – 11 ft.
No wind at final sag – 14 ft.
Air gap at structure – 8 ft. minimum

For 69/138kV lines:
6-psf wind at final sag – 9 ft.
No wind at final sag – 12 ft.
Air gap at structure – 4 ft. minimum

2.7 <u>Right-of-Way Width</u>

The minimum right-of way (ROW) width for typical double circuit 500 kV lines shall be a minimum as specified by PJM. The minimum right of way width for single circuit 500kV lines shall be 200 ft., for double circuit 230kV lines shall be 150 ft. and for double circuit 69 / 138kV lines should be 100 ft. Additional right of way may have to be acquired to support and accommodate special line designs and might be required to support lines constructed in heavily wooded areas such as certain sections of the Poconos or to support special access roads and specific construction needs..

2.8 <u>Insulator Assemblies</u>

Custom-designed 500kV and 230kV transmission line projects must use toughened-glass or porcelain insulator assemblies for both suspension and dead-end units. It is strongly suggested that 138kV and 69kV transmission line projects use porcelain insulator assemblies. Toughened glass could be used with prior permission from PPL. Because of recent polymer insulator failures and additional maintenance required, PPL is no longer allowing the use of polymer insulators on the transmission system. The following criteria shall be met for suspension and dead end units:

For 500kV designed transmission lines:

- ANSI Class 52-11 toughened glass or comparable porcelain units
- Ball and Socket type
- 11”diameter
- 6-1/8” long
- 50K M&E strength
- 25K proof test load
- 25K maximum working load
- Number of bells used:
  - dead end – 27 (quad string), 108 total per assembly
  - suspension vee-string assembly – 25 each leg, 50 total per assembly
  - long span suspension vee-string assembly – 50 each leg (double string), 100 total per assembly
- Interior angle of tangent vee strings 49 degrees
- The allowable insulator strength as specified in NESC Rule 277 must not be exceeded for NESC Rule 250B loads.
- The tension in the conductor under NESC Heavy loading with overload factors shall not exceed 50% of the ultimate strength of the insulator assembly. (NESC 250B loads without overload factors ≤ 50% ultimate strength)
- For the special load cases specified in this document, 80% of the rated strength of an insulator shall be used for the allowable strength.

For 230kV, 138kV and 69kV designed transmission lines:

- ANSI Class 52-11 toughened glass or compatible porcelain units
- Ball and Socket type
- 10” diameter
- 5-3/4” long
- 30K M&E strength
- 15K proof test load
- 15K maximum working load
- Number of bells used:
  - 230kV dead-end – 18 (double string), 36 total assembly
  - 69 / 138kV dead-end – 12 (single string) 12 total assembly
  - 230kV suspension – 16 (single string) 16 total assembly
  - 69 / 138kV suspension – 10 (single string) 10 total assembly
  - Note: special designed spans may require special double and / or triple stings in order to accommodate extreme loading conditions
- Insulator loading requirements and maximum design angles must be followed if strut type or horizontal line post type insulator assemblies are being used as part of the line design.
- The allowable insulator strength as specified in NESC Rule 277 must not be exceeded for NESC Rule 250B loads.
- The tension in the conductor under NESC Heavy loading with overload factors shall not exceed 50% of the ultimate strength of the insulator assembly. (NESC 250B loads without overload factors <= 50% ultimate strength).

2.9 Grounding and Lightning Performance

The maximum acceptable structure ground resistance shall be 15 Ohms for 500kV as required by PJM and 25 Ohms for 230kV, 138kV and 69kV designed lines. Individual structure grounding measurements will be allowed to exceed the required 15 Ohm and 25 Ohm value only if the average value for the 5 adjacent structures along the line is less than the 15 Ohms or 25 Ohms. Chemical grounding is not permitted as a way of reducing ground resistance.

Lightning performance calculations are to be based on an Isokeraunic level of 40 thunderstorm days/year and performed using EPRI's T-FLASH program or an accepted equivalent. Performance standard is 1.0 outage per 100 circuit miles per year for 500kV designed transmission lines, 2.0 outages per 100 circuit miles per year for 230kV designed transmission lines, 3.0 outages per 100 circuit miles per year for 138kV designed transmission lines and 4.0 outages per 100 circuit miles per year for 69kV designed transmission lines.

2.10 Phasing

Conductor phasing shall be determined on a project by project basis.

2.11 Foundation Design Guidelines / Requirements

1.) All transmission line custom steel pole structures and any guy anchors shall be supported by drilled reinforced concrete caissons. The foundations shall be designed per current industry standards and the designer shall use EPRI FAD or PLS Cad's Caisson foundation design computer program.

2.) FAD Program inputs (pole loading, soil conditions data from core borings and Geo – Tech report output) and output results shall be provided to PPL EU. The designer must perform a geotechnical and subsurface investigation at each foundation structure location that will include a boring to determine the soil parameters to be used in the design.

3.) The final Foundation Design Package provided to PPL EU shall include the foundation design and anchor bolt drawings on PPL EU standard A and C size drawing formats.

4.) "Rock Anchor" solutions are prohibited. Excavation into rock is the accepted methodology.

5.) If shallow bedrock is encountered in the soil borings, the caisson foundations shall be designed to be embedded into solid rock a length equal to at least one caisson diameter.

6.) The PPL EU Performance Criteria to be utilized are related to the maximum displacement and rotation at the top of the concrete as follows:
* Total Displacement = 4 inches
* Non-Recoverable Displacement = 2 inches
* Total Rotation = 2 degrees
* Non-Recoverable Rotation = 1 degree

7.) The ultimate strength of overturning moment and uplift of the foundation shall not be less than 1.25 times the design factored load reactions of the structure. The ultimate strength of foundations subjected primarily to compression load shall be not less than 1.10 times the design factored load reaction of the structure. Overturning moment foundations designed by rotation or pier deflection performance criteria shall use factored structure reactions for determination of the foundation performance.

8.) The minimum caisson diameter for each structure shall be the custom designed steel pole manufacturer's anchor bolt circle diameter plus 25 inches rounded up to the nearest even foot increment. However, the minimum desired shaft diameter shall be no less than 5.50 feet. The maximum shaft diameter is desired to be the minimum pier diameter plus 1.00 foot.

9.) The pedestal height above ground line shall be designed with a minimum of 12 inches of reveal above final grade unless prior approval is given by PPL EU.

10.) As a guideline, any direct embedded custom steel structure will require a minimum embedment depth of 10% plus 4' and could require a greater embedment depth in areas with substandard / poor soil conditions. PPL EU standard practice requires a drilled shaft caisson foundation for all structures with moment loads over 1,200 foot-kips.

11.) Concrete foundations shall be designed and installed in accordance with PPL Concrete Materials & Placement Specification A-190975 and Concrete Materials Specification A-190974.

2.12 Plan and Profile

Plan and profile drawings shall be completed in AutoCAD format on 34"x 44", "E" size drawings with a scale of 1" = 200' horizontal and 1" = 20' vertical. Conductors will be shown at their maximum operating temperature and / or maximum sag condition whichever is greater.

2.13 Transmission Pole Spotting Criteria

1. Minimize contact with environmentally sensitive areas, streams, forested areas, or other valuable natural habitats.

2. Minimize contact with property parcels that have incompatible zoning or land use planning classifications.

3. Minimize contact with areas where terrain or drainage would interfere with transmission line construction and maintenance.

4. To the extent practical, if any existing structures require replacement, the structure should be replaced on a structure-for-structure basis. All new structures will be placed as close as possible (either ahead or back along the centerline) to the existing structures

5. The structures at line angle points (P.I.'s) will be placed in the same location as the existing structures. Temporary structures will be used during construction to support the existing circuit in order to remove the existing P.I. structure and replace with a new structure.

6. Where the rights-of-way are sufficiently wide, new structures will be placed along side of the existing structures to facilitate a 10-hour return to service time of existing transmission lines during construction or unless prior approval is granted PPL EU.

7. Some structure locations may be shifted significantly for more optimal design or as dictated by environmental factors.

2.14 Electrical Environmental Effects Criteria

Electrical Environmental Effects Criteria will be supplied to the Developer on a project by project basis. At this time the Developer should follow the PJM recommendations for the maximum electric field value, audible noise, and radio noise at edge of right of ways.

Maximum voltage = 500 kV x 1.10 or 550 kV
Maximum voltage = 230 kV x 1.05 or 241.5 kV
Maximum voltage = 138 kV x 1.05 or 144.9 kV
Maximum voltage = 69kV x 1.05 or 72.45 kV

Lowest conductor height above ground (HVTRC Calculation Method) = 53 ft. for 500kV, 32 ft. for 230kV and 30 ft. for 69/138kV.
Audible noise wet conductor (L5-) conditions dB (A scale)
Radio noise fair weather, measurement frequency 1 MHz
Field strengths should be measured at 1 meter above ground line

APPENDIX “A” TABLE VI
PPL TRANSMISSION LINES
VERTICAL CLEARANCES IN FEET OF PHASE CONDUCTORS AND
GUYS ABOVE GROUND, ROADWAY, RAIL OR WATER SURFACES
CONDUCTOR AT MAXIMUM DESIGN TEMPERATURE

	LINE PH TO PH DESIGN VOLTAGE				
NATURE OF CROSSING	69 KV	138 KV	230 KV	500 KV	GUYS
1. Railroad tracks*	31	32	34	53	27
2. Surfaces traversed by vehicles	30	30	32	53 **	19
3. ROADS (FUTURE LOWER voltage lines)	49	51	53	58	
4. Pedestrian space or restricted traffic ***	30	30	32	53	17
5. Water areas not suitable for sailboats	30	30	32	53	17
6. Water areas suitable for sail boating with an unobstructed surface area of:					
a. Less than 20 acres	30	30	32	53	21
b. 20 to 200 acres	33	34	36	53	29
c. 200 to 2000 acres	39	40	42	53	35
d. Over 2000 acres	45	46	48	54	41
7. Land posted for rigging or launching sailboats	Clearance SHALL be 5.0 feet greater than in 6 above for the type of water areas served by the launching site.				
8. Gas transmission lines (Not NESC)	30	30	32	53	30

***** Developer must contact all local Railroads to determine minimum clearance requirement above top rail.

****** Increase this clearance as required to limit electrostatic effects to < 5 ma on a large vehicle. Conductor at final unloaded sag at 120 Deg. F.

******* Equestrians, vehicles and other mobile units > 8 feet high are prohibited.

APPENDIX “A” TABLE VIII
PPL TRANSMISSION LINES
VERTICAL CLEARANCES IN FEET BETWEEN WIRES
CONDUCTORS AND CABLES ON DIFFERENT STRUCTURES,
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE				
LINE AT LOWER LEVEL	69 KV	138 KV	230 KV	500 KV	GUYS
1. Communication cables	9	11	13	18	5
2. Covered supply cables 0 to 750 volts	6	8	10	15	5
3. Open supply cables 0 to 750 volts Covered supply cables Over 750 volts	6	8	10	15	5
4. Open supply cables					
4 to 22 kV	6	8	10	15	5
69 kV	7	8	10	16	6
138 kV	9 *	10	12	18	8
230 kV	11 *	13 *	14	19	10
500 kV	17 *	19 *	21 *	25	15
5. Trolley and electrified railroad contact conductors and assoc. span & messenger wires	10	12	14	19	7
6. Guys, span wires, multi grounded neutral conductors and surge protection wires	8	10	12	17	5
9. Voltage increment	0.7	2.2	4.1	9.9	0

Clearances are based on the basic code clearance from Table 233-1 of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

Clearances are for vertical crossings with the top conductor at final sag determined from the maximum design conductor temperature and the bottom conductor at 0 Deg. F initial sag.

***** Crossings of lower voltage lines over higher voltage lines are not recommended.

APPENDIX "A" TABLE IX
PPL TRANSMISSION LINES
HORIZONTAL CLEARANCES IN FEET BETWEEN WIRES,
CONDUCTORS AND CABLES ON DIFFERENT STRUCTURES
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE				
LINE AT LOWER LEVEL	69 KV	138 KV	230 KV	500 KV	GUYS
1. Communication cables	9	11	13	18	8
2. Covered supply cables 0 to 750 volts	9	11	13	18	8
3. Open supply cables 0 to 750 volts Covered supply cables Over 750 volts	9	11	13	18	8
4. Open supply cables 4 to 500 kV	9	11	13	18	18
5. Trolley and electrified railroad contact conductors and assoc. span & messenger wires	9	11	13	18	8
6. Guys, span wires, multi grounded neutral conductors and surge protection wires	9	11	13	18	5
9. Voltage increment	0.7	2.1	4.1	9.9	0

Clearances are based on the basic code clearance from Rule 233B-1 of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

Clearances are for crossings where the uses of conductor envelopes are needed to determine the clearance between skewed crossing conductors. Follow the procedure in Figures 233-1 to 233-2 to determine clearance. To avoid this procedure make all crossings at near 90 degrees or provide attachments to the crossing structure for lower voltage lines.

APPENDIX “A” TABLE X
PPL TRANSMISSION LINES
CLEARANCES IN FEET BETWEEN WIRES, CONDUCTORS
AND CABLES TO OTHER SUPPORT STRUCTURES
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE				
CLEARANCE CONDITION	69 KV	138 KV	230 KV	500 KV	GUYS
1. Horizontal with cable at rest	8	10	12	17	6
2. Horizontal with wind deflection of cable	8	9	11	17	
3. Vertical	9	10	12	18	5
4. Voltage increment	0	1.3	3.2	8.9	0

Clearances are based on the basic code clearance from Rule 234B of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

Horizontal clearance with cable at rest is from the conductor at maximum vertical sag (thermal or ice) no wind.

Horizontal clearance with wind is with the conductor displaced from the vertical by a 6 psf wind at 60 deg. F final sag. Deflection of suspension insulators and flexible structures must be included.

Vertical clearance is with the conductor at a maximum operating temperature > 120 Deg. F final.

APPENDIX “A” TABLE XI
PPL TRANSMISSION LINES
CLEARANCES IN FEET BETWEEN WIRES, CONDUCTORS AND CABLES TO BUILDINGS, SIGNS, BILLBOARDS, CHIMNEYS, ANTENNAS, TANKS AND OTHER INSTALLATIONS EXCEPT BRIDGES
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE				
CLEARANCE OF	69 KV	138 KV	230 KV	500 KV	GUYS
1. BUILDINGS					
Horizontal with cable at rest	12	13	15	21	8
Horizontal with wind deflection of cable	9	10	12	18	
Vertical					
Over or under roof or projections not accessible	17	18	20	26	6
Over or under roofs and balconies that are accessible but not to truck traffic	18	19	21	27	14
Over roofs with truck traffic	23	24	26	32	19
2. SIGNS					
Horizontal with cable at rest	12	13	15	21	6
Horizontal with wind deflection of cable	9	10	12	18	
Vertical					
Over or under catwalks or other surfaces upon which personnel walk	18	19	21	26	14
Over or under other portions of such installations	12	14	16	21	6
3. VOLTAGE INCREMENTS	0.7	2.2	4.1	9.9	0

Clearances are based on the basic code clearance from Rule 234C of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

Horizontal clearance with cable at rest is from the conductor at maximum vertical sag (thermal or ice) no wind. Horizontal clearance with wind is with the conductor displaced from the vertical by a 6 psf wind at 60 deg. F final sag. Deflection of suspension insulators and flexible structures must be included. Vertical clearance is with the conductor at a maximum operating temperature > 120 Deg. F final.

APPENDIX “A” TABLE XII
PPL TRANSMISSION LINES
CLEARANCES IN FEET BETWEEN RIGID LIVE PARTS
TO BUILDINGS, SIGNS, BILLBOARDS, CHIMNEYS, ANTENNAS,
TANKS AND OTHER INSTALLATIONS EXCEPT BRIDGES
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE			
CLEARANCE OF	69 KV	138 KV	230 KV	500 KV
1. BUILDINGS				
Horizontal	11	13	15	20
Vertical				
Over or under roof or projections not accessible	16	18	20	25
Over or under roofs and balconies that are accessible but not to truck traffic	17	19	21	26
Over roofs with truck traffic	22	24	26	31
2. SIGNS				
Horizontal	11	13	15	20
Vertical				
Over or under cat-walks or other surfaces upon which personnel walk	17	19	21	26
Over or under other portions of such installations	12	13	15	21
3. VOLTAGE INCREMENTS	0.7	2.2	4.1	9.9

Clearances are based on the basic code clearance from Rule 234C of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

Horizontal clearance with cable at rest is from the conductor at maximum vertical sag (thermal or ice) no wind.

Vertical clearance is with the conductor at a maximum operating temperature > 120 Deg. F final.

APPENDIX “A” TABLE XIII
PPL TRANSMISSION LINES
CLEARANCES IN FEET BETWEEN WIRES, CONDUCTORS, AND CABLES TO BRIDGES
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE			
CLEARANCE	69 KV	138 KV	230 KV	500 KV
1. OVER BRIDGES				
Attached	10	11	13	19
Not attached	17	18	20	26
2. BESIDE, UNDER OR WITHIN BRIDGE STRUCTURE				
Accessible portions of the bridge				
Attached	10	11	13	19
Not attached	12	13	15	21
Not attached with wind deflection	9	10	12	18
Inaccessible portions of the bridge				
Attached	10	11	13	19
Not attached	11	12	14	20
Not attached with wind deflection	9	10	12	18
3. Voltage Increments	0.7	2.2	4.1	9.9

Clearances are based on the basic code clearance from Rule 234D of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.
This rule does not apply to guys and multi grounded surge protection wires.

Horizontal clearance with cable at rest is from the conductor at maximum vertical sag (thermal or ice) no wind. Horizontal clearance with wind is with the conductor displaced from the vertical by a 6 psf wind at 60 deg. F final sag. Deflection of suspension insulators and flexible structures must be included.

Vertical clearance is with the conductor at a maximum operating temperature $>$ 120 Deg. F final.

Where over traveled ways on or near bridges, the clearances of Rule 232 also apply.

APPENDIX “A” TABLE XIV
PPL TRANSMISSION LINES
CLEARANCES IN FEET BETWEEN UNGUARDED RIGID LIVE PARTS TO BRIDGES
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE			
CLEARANCE	69 KV	138 KV	230 KV	500 KV
1. OVER BRIDGES				
Attached	9	11	13	18
Not attached	16	18	20	25
2. BESIDE, UNDER OR WITHIN BRIDGE STRUCTURE				
Accessible portions of the bridge				
Attached	9	11	13	18
Not attached	11	13	15	20
Inaccessible portions of the bridge				
Attached	9	11	13	18
Not attached	10	12	14	19
3. Voltage Increments	0.7	2.2	4.1	9.9

Clearances are based on the basic code clearance from Rule 234D of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.
This rule does not apply to guys and multi grounded surge protection wires.

Horizontal clearance with cable at rest is from the conductor at maximum vertical sag (thermal or ice) no wind.

Vertical clearance is with the conductor at a maximum operating temperature > 120 Deg. F final.

Where over traveled ways on or near bridges, the clearances of Rule 232 also apply.

APPENDIX “A” TABLE XV
PPL TRANSMISSION LINES
CLEARANCES IN FEET BETWEEN WIRES, CONDUCTORS
AND CABLES PASSING OVER OR NEAR SWIMMING AREAS
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE AT UPPER LEVEL LINE PH TO PH DESIGN VOLTAGE				
CLEARANCE CONDITION	69 KV	138 KV	230 KV	500 KV	GUYS
A. In any direction from water level, edge of pool, base of diving platform, or anchored raft	29	31	33	38	25
B. In any direction to the diving platform or tower	21	23	25	30	17
C. Vertical clearance over adjacent land	Clearance shall be as required by Rule 232.				
Voltage increments	0.7	2.2	4.1	9.9	0

Clearances are based on the basic code clearance from Rule 234E of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

Horizontal clearance with wind is with the conductor displaced from the vertical by a 6 psf wind at 60 deg. F final sag. Deflection of suspension insulators and flexible structures must be included.

Vertical clearance is with the conductor at a maximum operating temperature > 120 Deg. F final.

This rule does not apply to guys and multi grounded surge protection wires when they are more than 10 feet horizontally from the edge of the pool, diving platform, or diving tower.

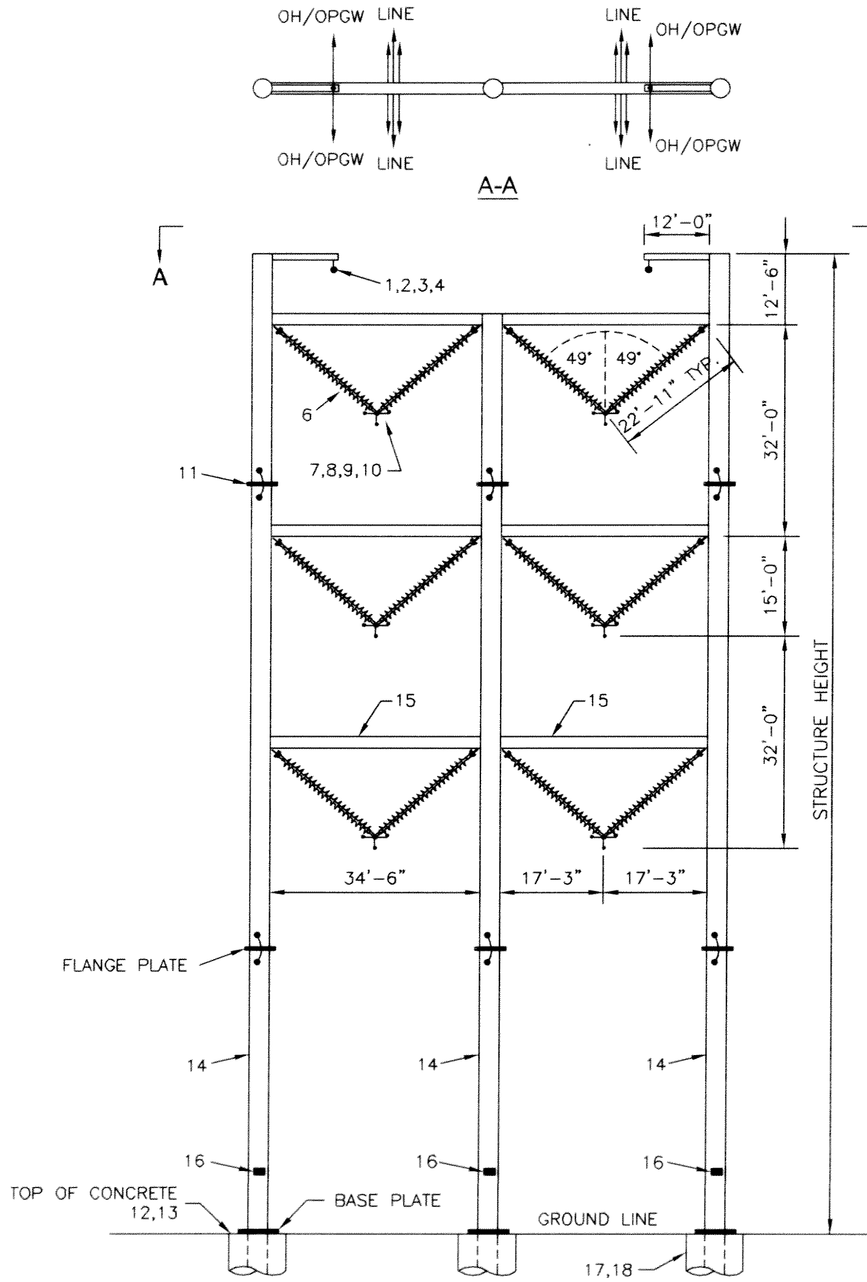
TABLE XVI
PPL TRANSMISSION LINES
CLEARANCE IN FEET IN ANY DIRECTION FROM LINE CONDUCTORS TO SUPPORTS AND CABLES ATTACHED TO THE SAME SUPPORT
BASED ON 2012 EDITION OF THE NATIONAL ELECTRICAL SAFETY CODE

	LINE PH TO PH DESIGN VOLTAGE			
Clearance of line Conductors from	69 KV	138 KV	230 KV	500 KV
1. Vertical & Lateral Conductors				
Of the same circuit* (0.25/kV)	6	7	9	16
*Over 50kV none specified. This chart uses 20” adjusted from ‘Other Circuits’				
Of other circuits (0.40/kV)	6	9	12	22
Communication antennas (0.40/kV)	6	9	12	22
2. Span or guy wires, or messengers attached to same structure				
When parallel to line (0.40/kV)	7	9	12	23
Anchor guys (0.25/kV)	5	7	9	15
All other (0.40/kV)	6	9	12	22
3. Surface of support arms (0.20/kV)	5	6	8	13
4. Surface of structures				
On jointly used structures (0.20/kV)	5	6	8	13
All other (0.20/kV)	5	6	8	13
4. Service drops (in the span)				
Communication (0.40/kV)	8	11	14	24
Supply (0.40/kV)	7	9	12	23

Clearances are based on the basic code clearance from Rule 235E of the 2012 NESC plus the voltage increment(s) and a minimum three (3) foot contingency.

With the conductor displaced by a 6 psf wind at 60 deg. F final sag, the above clearances must still be met. Displacement shall include deflection of flexible structures and fittings.

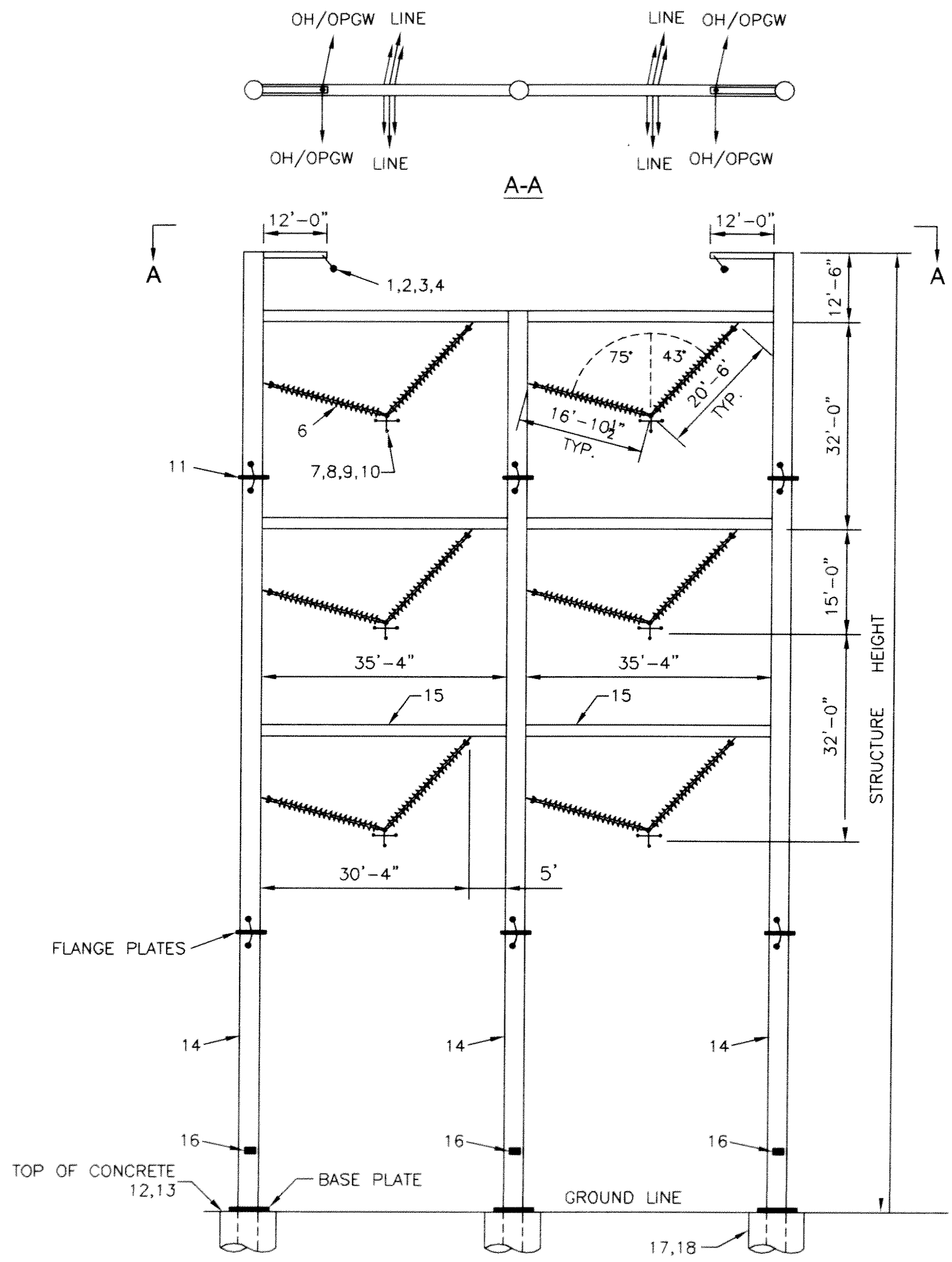
6-46-078	500KV STEEL POLE LINE CONSTRUCTION	6-46-078
SHEET 1	DOUBLE CIRCUIT- THREE POLE STRUCTURE TANGENT AND LIGHT ANGLE 0° TO 1° 5DMT__H FOR SPANS GREATER THAN 700 FEET	SHEET 1



TRANSMISSION CONSTRUCTION SPECIFICATIONS PPL ELECTRIC UTILITIES CORPORATION	DATE:________ DRAFTER: ASH SPONSOR:________ APPROVED:________ MGR. T & D DESIGN

500KV STEEL POLE LINE CONSTRUCTION
DOUBLE CIRCUIT-THREE POLE STRUCTURE
RUNNING ANGLE STRUCTURE 2° TO 20° 5DMA__H

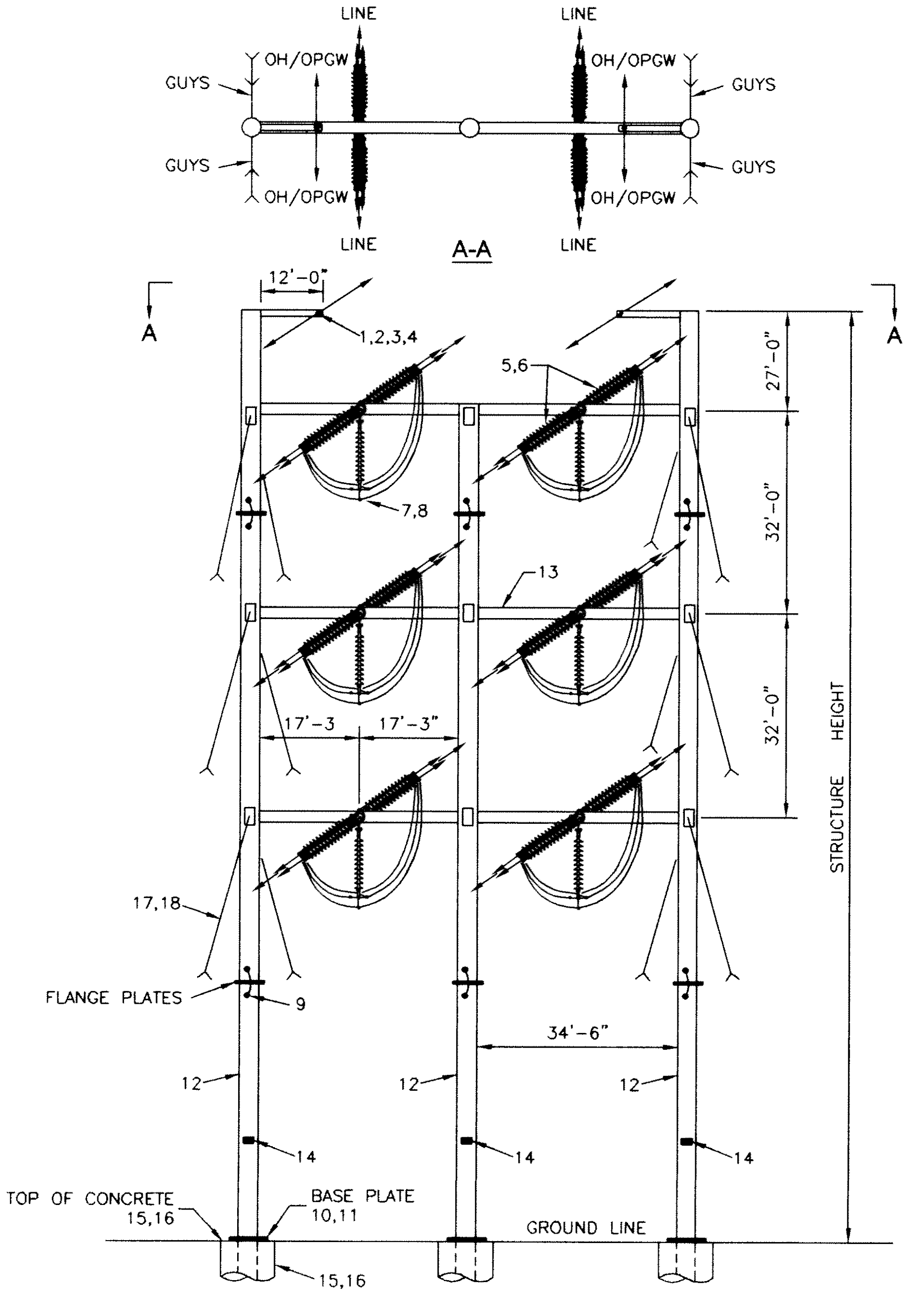
6-46-080
SHEET 1



TRANSMISSION CONSTRUCTION SPECIFICATIONS PPL ELECTRIC UTILITIES CORPORATION	DATE:______ DRAFTER: ASH SPONSOR:______ APPROVED:______ MGR. T & D DESIGN

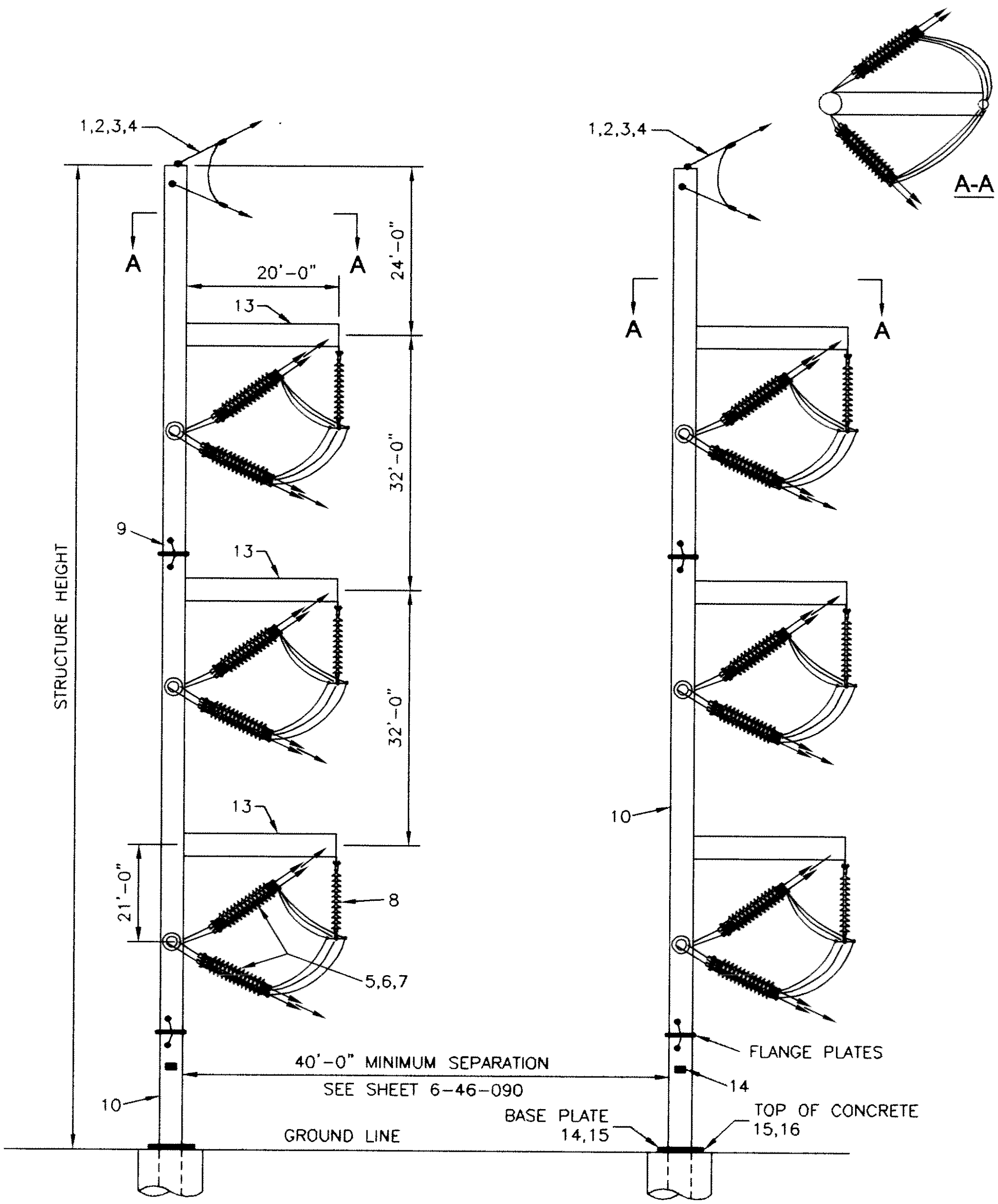
6-46-080_S001.dwg

6-46-082	500KV STEEL POLE LINE CONSTRUCTION DOUBLE CIRCUIT-THREE POLE IN-LINE DEAD END OR TENSION CHANGE TYPE 5DMD__HG	6-46-082
SHEET 1		SHEET 1



TRANSMISSION CONSTRUCTION SPECIFICATIONS PPL ELECTRIC UTILITIES CORPORATION	DATE:________ DRAFTER: ASH SPONSOR:________ APPROVED:________ MGR. T & D DESIGN

6-46-084	500KV STEEL POLE LINE CONSTRUCTION DOUBLE CIRCUIT – TWO POLE HEAVY ANGLE STRUCTURE ANGLES GREATER THAN 20° (AT REDUCED TENSION) TYPE 5DMD__ L/R	6-46-084
SHEET 1		SHEET 1



TRANSMISSION CONSTRUCTION SPECIFICATIONS PPL ELECTRIC UTILITIES CORPORATION	DATE:________ DRAFTER: ASH SPONSOR:________ APPROVED:________ MGR. T & D DESIGN