Prepared by [redacted]

OVERHEAD TRANSMISSION LINE DESIGN CRITERIA 068177

Asset Type: Electric Transmission [redacted] **Function:** Construction and Maintenance

Issued by: [redacted] **Date:** 12–17–2020

Rev. #14: This document replaces PG&E Document 068177, Rev. #13. For a description of the changes, see Page 24.

Table of Contents

Purpose and Scope

Proper transmission line (T/L) design requirements are necessary for the safe, reliable, and economic construction and operation of high–voltage transmission lines. This document outlines the minimum criteria to be used in the design of all PG&E overhead transmission lines. The electrical and structural limitations described in the criteria may be increased depending on local conditions or specific project–related requirements. The use of the criteria is intended only for experienced employees with a working knowledge of transmission line design and construction practices.

Any deviations from this design criteria resulting in the lowering of the electrical clearances or mechanical safety factors below *General Order (G.O.) 95* are not allowed. Deviations resulting in less than criteria requirements but still meeting *G.O. 95* should be made only under unusual circumstances. If a deviation is made from the design criteria, the project engineer shall submit a letter describing the deviation and giving the reasons for the deviation or criteria change. If structural loading is involved, a civil engineer must approve and sign off on the letter. The supervisors of T/L engineering and T/L standards personnel must also approve and sign the letter. The signed letter shall be included in the job file for future reference.

References	Location	Document No.
Methods of Grounding Steel Transmission Poles and Towers	TIL	012566

Wood and Wood pole equivalent Transmission (Light Duty Steel Pole, Fiberglass Reinforced Polymer, etc...)

The design criteria for wood pole line construction are described in Documents 048874A and 032583. The design for all wood poles and Light Duty Steel Poles (LDSPs) construction is 115 kV with the following exceptions:

1. In situations where the existing 60/70 kV transmission line has been reinsulated to 115 kV, note that if the existing substations are 60/70 kV (without a lightning arrester between the line and the station bus), then the last two transmission line structures into the station need to remain insulated at 60/70 kV, in order to prevent flashing the station bus due to insulator mis-coordination. On non-conductive poles, pole hardware needs to be grounded.
2. Retain 60–70 kV switches and switch installations. Install spill gaps on 115 kV insulated structures ahead and back of 60–70 kV switches.
3. For re-conductor projects, maintain 60–70 kV phase spacing if existing poles are correctly sized for the new conductor and pole replacements can be avoided.
4. When 60/70 kV spacing and insulation is required for aesthetic and permit reasons, 60/70 kV phase-to-phase separation can be used.
5. Refer to Table 7 on Page 10 for minimum separation between phase conductors and overhead ground wires.
6. Refer to Table 8 on Page 10 for conductor tension criteria.

Where 60–70 kV circuits are constructed at 115 kV, transmission line estimator or engineer must communicate the design information to system protection personnel and substation engineering personnel.

Structural Requirements

Steel poles (LDSP, Engineered Direct Embedded Pole (EDEP), etc.) are the required support structure unless prohibited by Table 1 on Page 4, for replacing wood poles, and for new construction. **Broken wire requirements need to be considered (GO95 Rule 47.2 and 47.3) under all conditions for wood, composite, and steel.** For LDSPs, weathering steel (Corten) shall be used unless requested by project requirements. Galvanized steel is required in areas with high human density, coastal or other wet environments. Using the boundaries in GIS (Geographic Information System or Document 032911) consider the Severe/Moderate corrosion areas to be coastal or other wet environment. For all other environments use weathering steel (corten).

Decision Matrix for Light Duty vs. Tubular Steel Poles (TSP):

Preferred installation is LDSP since the economic advantages LDSP result in costs roughly 3x less than TSPs, unless these issues are present:

- Design constraints that prevent the use of light duty steel poles include but are not limited to the following:
  - Live line maintenance is necessary, but cannot always be achieved with a LDSP
  - LDSP structure height and class would be insufficient to meet clearance and strength criteria
  - Insufficient room to install anchors and guys, necessitating a self-supporting structure.
  - If broken wire capability cannot be achieved with a LDSP, then use alternative structure type.
  - If broken wire criteria is present in a pole or tower line it must be maintained to ensure the stability of the adjacent structures.
  - 115 kV switches can be installed on a TSP or Tower without restrictions. 115 kV switches cannot be installed on a LDSP without detailed structural analysis and review of shop drawings by Engineering.
  - 60/70 kV switches can be installed on EDEP or LDSP if switches are either unitized or channel mounted and supported with bearing plates.
  - For structures that are to support switches, flange joints are required. Other means of preventing pole shaft slippage can be used after engineering approval.

Wood and Wood pole equivalent Transmission (Light Duty Steel Pole, Fiberglass Reinforced Polymer, etc...)(continued)

- Steel lattice poles can be used instead of TSPs in some applications (lattice poles can be designed by vendor, saving engineering/design costs)
  - Drawing 399288 define the load limits for suspension steel lattice poles
  - Drawing 399309 define the load limits for dead end steel lattice poles
  - Small line angles that do not need guying

Table 1 The following criteria shall be used to determine the structure material

Review each row below for applicability to ensure all conditions are satisfied. Facility rearrangement or structures other than those specified below may be necessary to mitigate all conditions in rare cases.

Facility attached to or proposed	With common neutral		Without common neutral	
	Wood pole	Steel pole [1]	Wood pole	Steel pole [1]
Distribution underbuild primary wires	No	Yes	No	Yes
Distribution, Secondary or Service Risers	Yes	No	Yes	No
Secondary or Service wire feeding third party	No	Yes	Yes	No
Distribution transformer feeding third party customer	No	Yes	Yes	No
Non−dielectric (conductive) third party communication including messenger wire	No	Yes	Yes	No [5]
ADSS & OPGW fiber optic communication	No	Yes	No	Yes
Transformer feeding PG&E only equipment	No	Yes	No	Yes
Distribution equipment (Capacitors, reclosers etc.)	Yes	Yes	Yes	Yes
Right of Way or permit specifies wood poles only	Yes	No [2]	Yes	No [2]
Within 8 feet of conductive object imbedded in, and is extending above the ground	Yes	No	Yes	No
Transmission switch	No	Yes	No	Yes [4]
Within 25 feet of underground metal pipeline	Yes	Study [3]	Yes	Study [3]

1 Steel pole criteria also applies to any structure with a continuous metalic path from the transmission level to ground.
2 It is recommended that land negotiate to permit the use of steel poles.
3 Contact ATS to perform an “arc distance” hazard assessment to determine the safe distance between the pole (including associated grounds), and the pipe.
4 As long as all criteria in Table 1 are met without other prohibiting factors allowing steel pole without common neutral.
5 New attachment requests should be rejected. Existing attachments are permitted such as when replacing a wood pole with a steel pole after explaining the potential hazard of transmission fault current on the communication facility to the third party.
6 Temporary shoo−fly may use wood pole construction otherwise follow table 1. Deviation to Table 1 would require submission of a waiver TD−3310P−01.

The minimum pole class, due to transverse loading and setting depth, shall be determined using Document 032550. or PLS−CADD using standard criteria files. The minimum pole class, due to column loading, shall be determined using Document 015203 or PLS-CADD using standard criteria files. Additional structural limitation drawings are shown in Table 2 on Page 5.

Wood and Wood pole equivalent Transmission (Light Duty Steel Pole, Fiberglass Reinforced Polymer, etc...)(continued)

Table 2 Structural Limitation Drawings for 44-115 kV Wood Poles

Title	Document Number
Transverse Loading Design Criteria for 44-115 kV Pole Lines	032551
Single Vertical Limitations Design Criteria for 44-115 kV Pole Lines	032552A
Structural Limitations Design Criteria for 44-70 kV Pole Lines	032553
Structural Limitations Design Criteria for 115 kV Wood Pole Lines	048874A

The grade of construction for transmission wood pole lines 44 kV to 115 kV shall be in accordance with the following table (*G.O. 95*, Rule 42, Table 3, Page 5).

Table 3 Grade of Construction

Circuit at Upper Level	Condition	Grade of Construction Required
All Voltages	Crossing Major Railway	A
Over 5,000 V	Crossing, Joint With, or in Conflict With Communication Circuit	A
All Voltages	Crossing Minor Railway	B
Over 5,000 V	No Crossing Involved	B
Over 5,000 V	Distribution Under Build	B

Where two or more conditions affecting the grade of construction exist, the grade of construction used shall be the highest required under any of the conditions (*G.O. 95*, Rule 42.1). Any additional attachments to a pole will require that the pole be brought up to the full “at installation” safety factor requirements for the applicable grade of construction. (Note: The use of safety factor reduction for reconstruction or the addition of additional facilities, per GO 95 Rule 44.3, is not approved for transmission lines.)

An extreme wind loading criteria shall be applied to all new, relocated, reconductored and/or replaced transmission poles using the Extreme Wind safety factor in Table 4 below. This criteria is not applied whenever a pole is “touched,” such as when moving conductors, installing transformers, services, or installing communication facilities on an existing structure. To determine wind speed, use the wind speed values shown on PG&E’s extreme wind map in GIS. These wind speeds have been converted to a 3 – second gust value and are based off a 50 – year return period.

Wood poles, light duty steel poles, and FRP (Fiberglass Reinforced Polymer) poles that are installed or replaced for any reason, shall have the poles sized with the Safety Factors in Table 4 below. FRP poles shall be sized to match the deflection of the wood pole class equivalent.

Table 4 Minimum Safety Factors

Structure Type	Safety Factor		
	Grade A	Grade B	Extreme Wind
LDSP	2.5	N/A	1
FRP	2.5	N/A	1
Wood	5	4	1.33

Insulation Criteria

For wood pole and wood pole equivalent construction, non−ceramic insulators are company standard for post type Insulator applications. For suspension and dead-end applications, the insulator preference is in this order: glass then polymer. In areas of high contamination where washing is required on porcelain or glass insulators, use silicone undercoated glass to minimize the frequency of washing. Determine the number and type of insulators required for suspension and dead-end-type insulator strings, or the type of post insulators required for post construction, by the insulation district or contamination area. The insulation districts are shown in Document 026300. The number of units for contaminated areas is shown on Document 015014. Post-type construction is shown in Document 051762.

Wood and Wood pole equivalent Transmission (Light Duty Steel Pole, Fiberglass Reinforced Polymer, etc...) (continued)

60-70 kV Transmission Line Conversion to 115 kV Insulation

For future construction, existing 60−70 kV lines will be built using 115 kV type construction. Exceptions can be made for maintenance and minor reconstruction. When 60−70 kV circuits are constructed with 115 kV insulators and/or 115 kV phase−to−phase separation, System Protection and Substation Project Engineering must be informed so that the impacts can be assessed.
For 60−70 kV lines converted to 115 kV insulation, use the following criteria:

- 115 kV phase-to-phase and circuit-to-circuit separation.
- 115 kV material – insulators and hardware
- For reconductoring projects, maintain 60−70 kV framing. If the poles are in good condition and are correctly sized for the new conductor, do not change out poles. (Note: The use of safety factor reduction for reconstruction or the addition of additional facilities, per GO 95 Rule 44.3, is not approved for transmission lines.)
- To avoid replacing a good pole, use 60−70 kV phase−to−phase, circuit−to−circuit, and circuit−to−underbuild separation.
- When 115 kV insulation is used on a 60−70 kV line, gapped arresters should be installed between the line and the substation breaker.
- When 115 kV insulation is used on a 60/70 kV line, and if gapped arresters are not present (or there is uncertainty when the arresters will be installed), the last two transmission structures into the station require the use of 60/70 kV insulators or 115 kV post insulators with spill gaps in order to protect the station bus from possible insulator miscoordination. On wood poles and other poles made from non−conductive material, pole hardware needs to be grounded.
- Where structures are adjacent to 60/70 kV switches and insulated with 115kV post insulators, spill gaps must be installed on the structures adjacent to the switch. For installation of line spill gaps, see Document 051762.
- When structures are adjacent to 60/70 kV switches and insulated with either 115 kV suspension or dead−end insulators, the adjacent structures must be reinsulated to 60/70 kV.
- Install grounds on all structures with spill gaps or gapped arresters per drawing number 021904.
- Note: The intent of the insulation is to ensure same basic insulation level (BIL) on switch structure and adjacent structures.
- Install a 60/70kV switch on a 60/70kV rated line regardless of insulation.
- If existing poles are not adequate for a reconstruction project, then reconstruct using 115 kV insulation, clearances, and separations.

Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...)

Structural Requirements

Safety factors shall be based on the maximum conductor tension and under the maximum design wind load. For the **intact** conditions, all steel transmission line facilities shall be designed for *G.O. 95*, Grade ”A” construction safety factors. (See *G.O. 95*, Table 4, for a list of safety factors for each type of material.)
In addition to the above criteria, all steel structures shall be designed for **broken wire** criteria as described in Table 5. The conductors selected to calculate the broken wire longitudinal loads shall be selected so as to produce the maximum stress in the support structure. If the structure has an overhead ground wire, then the broken wire condition may include a broken ground wire in place of a broken conductor, if that produces the maximum stress. Grade A construction for steel structures is defined in CPUC *G.O. 95*, Rule 42. California high speed rail crossing shall be designed to meet all of the following design criteria per GO 176, Section 5.7.2:

1. Grade “A” construction strength for lines and structures.
2. Compliance with GO 95, Section XI.
3. Design and construction methods to prevent cascading failures from impacting the HSRS.
4. Dead−end construction for all crossing span lines and conductors.
5. No splices or taps on the span crossing the High−Speed Rail Right−of−Way.
6. Wooden poles are not permitted to support the span crossing the High−Speed Rail Right−of−Way.
7. Structures adjacent to the High−Speed Rail Right−of−Way guyed away from the Right−of−Way. Exceptions may be granted by the Agency for steel poles or towers which can support broken conductor loads.
8. Except in case of emergency and with the consent of the Agency, inspection and maintenance of such wires or lines, whether imposed by regulatory authorities or by the utility’s requirements, shall be performed without entering the High−Speed Rail Right−of−Way.

Table 5 Minimum Safety Factors

Structure Type	Number of Broken Wires	Safety Factor
Tangent Suspension	1/3 Wires Broken	1.0
Non-Terminal Dead End (new structure)	1/3 Wires Broken	1.5
Non-Terminal Dead End (rebuild)	1/3 Wires Broken	1.0
Terminal Dead End	All Wires Broken (see Note 1)	1.5
Substation Tap/Loop Dead End	All Wires Broken (see Note 2)	1.0

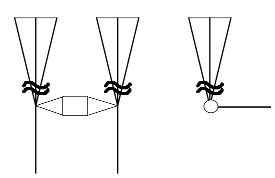

Figure 1
Terminal Dead End

Note:

1. A **terminal dead end** is defined as the first (or last) structure on a line at a substation or transition station. This structure should be capable of supporting the unbalanced load from the termination of all conductors on the high-tension or line side with a safety factor of 1.5 (see Figure 1).

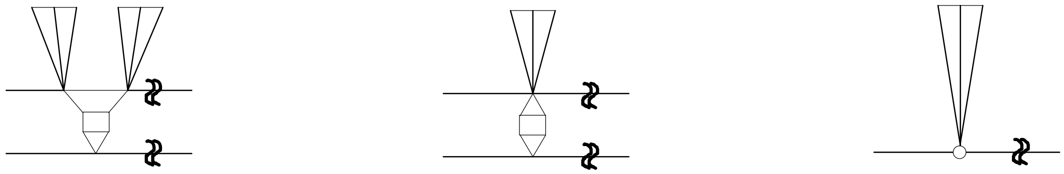

Figure 2
Substation Tap/Loop Dead End

Note:

2. A **substation tap/loop dead end** is defined as the structure in a transmission line that is used to tap−off or loop into a substation. This structure should be capable of supporting the termination of all conductors on the high−tension “main−line” side with a safety factor of 1.0 (see Figure 2).

Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...) (continued)

Anti-Cascade Loading Criteria

Towers on some existing tower lines may not be able to meet the broken wire criteria as specified above. Except for towers over Grade A crossings, the broken wire requirements for existing towers may be waived by the transmission line engineering supervisor, however, the line shall meet the cascade mitigation criteria given below. Towers over Grade A crossings shall meet the broken wire conditions as required by *G.O. 95*.

Per Rule 61.3-B of *G.O. 95*, a transmission line, as a whole, shall be designed so that a failure of an individual support structure shall not cause successive failures of more than 10 additional support structures. This can be accomplished by:

1. Having stop towers at intervals less than 10 towers.
2. Designing all towers for a minimum residual static load (RSL) at 1/3 of the conductor attachment points. For a single−circuit tower, apply the RSL at the attachment of any one conductor or one shield wire. For a double−circuit tower, apply the RSL at the attachments of any two conductors, or two shield wires, or one conductor and one shield wire.
3. Using load limiters to reduce unbalanced loads.

The use of Methods 2 and 3 above need pre−approval of the transmission line engineering supervisor.
The RSL for the conductor is the broken wire load based on everyday tension (EDT) at 60°F, no wind, no ice, final sag. The RSL for the shield wire is the full EDT load.

Maximum Loading Condition Criteria

The maximum loading condition is used to determine the maximum conductor tension, the minimum safety factors, and the broken wire loads.

Table 6 Maximum Loading Conditions

Loading Condition	Elevation (feet)	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
Light	0-1,500	25	0	8	Initial
Intermediate	1,501-3,000	0	1/4	6	Initial
Heavy	Over 3,000	0	1/2	6	Initial
Extra Heavy	As Required	0	3/4 or More	6	Initial

Initial is defined as the conductor tension at 1 hour for all loading areas and conductor types.

Elevations in Table 6 are the minimum guideline to determine snow loading. Some areas experience heavier snow loading then the elevation depicts in Table 6 and are reflected in both ETGIS and Snow Loading Map Document 054330. The more stringent of requirements between Table 6, ETGIS or Snow Loading Map 054330 shall govern. However, structures located at elevations over 3,000 feet shall be designed for heavy loading or greater. Experience with very wet snow may indicate that a particular line should be designed for greater than heavy loading.

Differential Ice Loading Requirements

The minimum distance between phase conductors of the same circuit and between phase conductors and overhead ground wire on the same structure under differential ice loading conditions is given in Table 7 on Page 10.

Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...) (continued)

Table 7 Momentary Minimum Separation in Any Direction Between Phase Conductors and Between Phase Conductors and Overhead Ground Wires

Voltage (kV)	Minimum Separation [1]	
	Phase-to-Phase (feet)	Phase-to-OHGW (feet)
60 and 70	1.8	1
115	3	1.8
230	6	3.5
500	NA [2]	8

[1] If one conductor is located directly above another, or if there is less than 1 foot of horizontal offset, maintain 2 feet of clearance, in addition to that specified in Table 7.
[2] In intermediate and heavy ice or snow loading areas, 500 kV construction shall be horizontal.

Conditions under which clearances apply:

- Upper Conductor – 32°F, final sag, with a radial thickness of ice equal to the maximum thickness of ice that can be reasonably expected for the geographical area.
- Lower Conductor – 32°F, final sag, no ice.

Extreme Wind Loading Criteria

The extreme wind loading criteria shall be applied on new construction, relocations, reconductor, and fiberoptic projects. This criteria is not applied whenever the tower is “touched”, such as when installing extensions to correct existing ground clearance infractions, modifications, or installation of communication antennas.

All new, relocated, replaced, and existing structures that are used for reconductoring and fiberoptic wire installations shall be designed for wind speed shown on PG&E’s extreme wind map. Wind pressure shall be calculated according to the National Electric Safety Code (NESC) 2002 based on 3-second gust wind speed and applied to the wires and structure with a safety factor of 1.0. PG&E’s extreme wind map shall show a 3-second gust speed.

Maximum Conductor Tension Criteria

The conductor tensions listed in Table 8 are for horizontal, bottom of the catenary tensions. Under no condition, should the resultant tension exceed 50% (*G.O. 95*, Rule 44, Safety Factors).

Table 8 Maximum Conductor Tension Criteria (Applies to Wood Poles also)

Conductor	Initial		Final
Type	Maximum Loaded	60°F	40°F
AAC	45%	35%	25% [1]
ACCR	45%	35%	25% [1]
ACSR	45%	35%	25% [1]
ACSS	45%	35%	25% [1]
Copper	45%	35%	25% [1]

[1] For span lengths between 1,800–2,500 feet, the maximum conductor tension shall not be greater than 22.5%. For spans greater than 2,500 feet, the maximum conductor tension shall not be greater than 20%.

Calculate the final sag to produce the maximum sag at one of the following two conditions:

- Final conductor sag after creep at 40°F, bare conductor.
- Final conductor sag after creep, with the loaded condition as described in Table 6 on Page 9.

Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...) (continued)

Insulation Criteria

Determine the number and type of insulators required for suspension and dead-end type insulator strings by the insulation district or contamination area. The insulation districts are shown in Document 026300. The number of units for contaminated areas is shown on Document 015014. Post-type construction is shown in Document 051762.

For suspension and dead−end insulator strings, the preference order is glass then porcelain for construction material. In areas of high contamination where washing is required on porcelain or glass insulators, use silicone undercoated glass to minimize the frequency of washing. For post insulators, non*ceramic insulators are preferred, though porcelain insulators may be substituted.

Requirements for hardware in corrosive areas are shown in Document 032911.

For all wood and steel construction, jumper support insulator strings shall be installed on dead-end loops to restrain the conductor during high wind conditions. On structures with line angles between 0 and 10 degrees, jumper support insulator strings shall be installed on all dead-end loops. On structures with line angles greater than 10 degrees, jumper strings shall be installed on dead-end loop on the outside angle only, the inside angle does not need a jumper string.

On dead-end structures with ceramic (porcelain or glass) insulator strings, the jumper support insulator string shall be made up with the appropriate number of ceramic suspension bells for that insulation district per Engineering Documents 026300 and 015014. On structures with box crossarms (typically lattice towers), jumper support insulator strings shall be installed on each corner of the crossarms. If box crossarm modifications are required, be sure that a working eye is include with the jumper support eye.

On dead-end structures with composite insulator strings, the jumper support insulator string shall be of composite type. Per Engineering Document 015014, Suspension−Type Insulators, conductor weights are required for composite type jumper string installations. Conductor hold down weights can be found in the “Transmission Line Standards” Book I (Beige Book). Drawing 053810 “Conductor Hold Down Weights for Overhead Transmission Lines”.

On deadend loops where no jumper support insulator string installation is required, the conductor loop must meet electrical clearances to the underside of the crossarm under wind conditions. For existing and proposed 115kV construction – i.e facilities with 115kV deadend insulation string assemblies − the belly of the deadend loop should be about 48 inches from the bottom of the crossarm. For existing 60/70kV construction – i.e. facilities with 60/70kV deadend insulation assemblies − the belly of the deadend loop should be about 36 inches from the bottom of the crossarm.

As a final check of the jumper installation, the conductor loop shall be pulled in towards the tower so that it is at a 45 degree angle. At this angle, the conductor clearance to structure (pole, crossarm, step bolts) must be at least 16” for 60/70kV, 26” for 115kV and 50” for 230 kV

Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...) (continued)

Open jumpers are to be cut as short as practical for the field condition and conductor size (see Table 9 for approximate lengths) allowing enough jumper tail remaining to permit connection with a suitable connector per 028854 − Connectors for Transmission Conductors. It is not permitted to have jumper tail long enough to impair electrical clearance or allow strand fatigue.

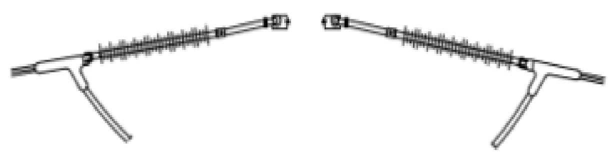

Figure 3
Open Jumper

- Maintain all electrical clearances when constructing open jumpers
- Dead−end jumpers are to be cut as short as practical for reconnecting on both sides of the dead−end
- Looping of jumpers and clamping on the main line is not allowed
- Open dead−end jumpers on bundled conductor are not to be tied together

Table 9 Open Jumper Lengths

Conductor Size	Approximate recommended length
Less than 4/0	2’
4/0 – 2300 kcmil	3’

- Actual lengths can be influenced by field conditions (i.e. framing configuration, conductor type, etc.) causing jumper tail lengths to be shorter or longer than Table 9.

Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...) (continued)

60-70 kV Transmission Line Conversion to 115 kV Insulation

For future construction, existing 60−70 kV lines will be built using 115 kV type construction. Exceptions can be made for maintenance and minor reconstruction. When 60−70 kV circuits are constructed with 115 kV insulators and/or 115 kV phase−to−phase separation, system protection and substation project engineering must be informed so that the impacts can be assessed.

For 60−70 kV lines converted to 115 kV insulation, use the following criteria:

- 115 kV phase-to-phase and circuit-to-circuit separation.
- 115 kV material – insulators and hardware.
- For reconductoring projects, maintain 60−70 kV framing. If the poles are in good condition and are correctly sized for the new conductor, − do not change out poles. (Note: The use of safety factor reduction for reconstruction is not approved for transmission lines.)
- To avoid replacing a good pole, use 60-70 kV phase-to-phase, circuit-to-circuit, and circuit-to-underbuild separation.
- When 115 kV insulation is used on a 60−70 kV line, gapped arresters should be installed between the line and the substation breaker.
- When 115 kV insulation is used on a 60/70 kV line, and if gapped arresters are not present (or there is uncertainty when the arresters will be installed), the last two transmission structures into the station require the use of 60/70 kV insulators or 115 kV post insulators with spill gaps in order to protect the station bus from possible insulator miscoordination. On wood poles and other poles made from non−conductive material, pole hardware needs to be grounded.
- Where structures are adjacent to 60/70 kV switches and insulated with 115kV post insulators, spill gaps must be installed on the structures adjacent to the switch. For installation of line spill gaps, see Document 051762.
- Where structures are adjacent to 60/70 kV switches and insulated with either 115kV suspension or dead−end insulators, the adjacent structures must be reinsulated to 60/70 kV.
- Install grounds on all structures with spill gaps or gapped arresters per drawing number 021904
- **NOTE:** The intent of the insulation is to ensure same basic insulation level (BIL) on switch structure and adjacent structures.
- Install a 60/70kV switch on a 60/70kV rated line regardless of insulation.
- Consider aesthetics − On delta or vertical post construction, do not mix 60−70 kV and 115 kV phase−to−phase separation
- If existing poles are not adequate for a reconstruction project, then reconstruct using 115 kV insulation, clearances, and separations.

Electrical Clearances

General Notes

1. Electrical clearances for all transmission lines must meet or exceed the requirements of *G.O. 95*. Use tables in this section for electrical clearance requirements.
2. Measure all clearances from surface to surface. Measure all spacing from center to center.
3. For clearance measurements, consider live metallic hardware that is electrically connected to line conductors as a part of the line conductors.
4. Increase all minimum clearances at the rate of 3% for each 1,000 feet in excess of 3,300 feet above mean sea level. (e.g. at 4300 feet mean sea level, minimum electrical clearances must be increased by 3.0%, at 5300 feet mean sea level, minimum electrical clearances must be increased by 6%, etc.)
5. If specific clearances are not identified in this document, use Document 022158 for clearance requirements.
6. Where additional circuits are installed under a 115 kV transmission circuit, the required conductor separation at the pole between the transmission conductor and distribution conductor is shown in Document 048873.
   For 60 and 70 kV transmission wood pole lines, the required conductor separation at the pole between transmission conductor and distribution conductor is listed in Document 022187. The midspan conductor separation shall meet or exceed the electrical clearance requirements in Document 022158 (for 115 kV lines, use *G.O. 95*, Table 2, Cases 8 – 13).

Criteria for Checking Minimum Electrical Clearances Above Ground, Roads, and Railroads

Table 10 Loading Conditions: Normal Clearances to Ground

Loading Condition	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
Light	60	0	0	Final
Intermediate	60 and 32	0 1/4	0 0	Final Final
Heavy	60 and 32	0 1/2	0 0	Final Final

Table 11 Loading Conditions: Emergency Clearances to Ground

Conductor Type	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
AAC	185 (85°C)	0	0	Final
ACCR	464 (240°C)	0	0	Final
ACSR	194 (90°C)	0	0	Final
ACSS	392 (200°C)	0	0	Final
Copper	185 (85°C)	0	0	Final

Electrical Clearances (continued)

Table 12 Standard Design Clearances to Ground [1]

Voltage	Situation	Normal Clearance (feet)	Emergency Clearance (feet)
500 kV	Cultivated Agriculture	40	33
500 kV	Other New Lines	37	33
500 kV	County Roads and Highway “X”	56	33
230 kV	New Line	32	29
230 kV	Rebuild Line	31	28
115 kV	New Line	32	29
115 kV	Rebuild Line	31	28
60–70 kV	New Line	32	29
60–70 kV	Rebuild Line	31	28
12 kV	All	25	22.5
Telephone	All	18	–

[1] The criteria for minimum clearance over railroad tracks and bodies of water are outlined in *G.O. 95*, Rule 37.

Criteria for Checking Minimum Electrical Clearances From Other Wires, Structures, and Supports

Table 13 Criteria for Checking Minimum Electrical Clearances From Other Wires, Structures, and Supports Loading Conditions: Electrical Clearance (all situations)

Condition	Circuit	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
No Wind	Upper	60	0	0	Final
With Wind	Lower	60	0	8	Final

Table 14 Loading Conditions: Clearance to Other Structure (minimum required electrical clearances must be maintained for each of the conductor conditions and the conditions in Table 13)

Loading Condition	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
Light	25 25 130	0 0 0	8 0 2	Initial Initial Final
Intermediate	0 25 25 130	1/4 0 0 0	6 8 0 2	Initial Initial Initial Final
Heavy	0 25 25 130	1/2 0 0 0	6 8 0 2	Initial Initial Initial Final

Electrical Clearances (continued)

Table 15 Loading Conditions: Clearance at Crossings and Underbuild (maintain the minimum required electrical clearances for each of the conditions and the conditions in Table 13)

Loading Condition	Case	Circuit	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
Light	1	Upper Lower	MOT [1, 2 ,3] 60	0 0	0 0	Final Final
Intermediate	1	Upper Lower	32 32	1/4 0	0 0	Final Final
	2	Upper Lower	MOT [1, 2 ,3] 60	0 0	0 0	Final Final
Heavy	1	Upper Lower	32 32	1/2 0	0 0	Final Final
	2	Upper Lower	MOT [1, 2 ,3] 60	0 0	0 0	Final Final

1 Clearances should be based on “Upper” circuit at its maximum operating temperature (MOT).

2 For ACSS conductor, use 392°F as the upper circuit operating temperature. For ACCR conductor, use 464°F as the upper circuit operating temperature.

3 For MOT of conductors other than ACSS and ACCR, see Document 030559, “Ampacity of Overhead Transmission Line Conductors”.

Minimum electrical clearances from other wires, structures, and supports are shown in Document 470591, “Electrical Clearances for 60 kV, 70 kV, 115 kV, and 230 kV Overhead Transmission Lines.” The clearances in this document have been established by an air gap analysis of PG&E’s voltage levels, maximum expected switching surges, and air quality. These values are very similar to the minimums set forth in the National Electric Safety Code (NESC). In all cases, these values meet or exceed the minimum values set forth in the CPUC’s *G.O. 95*.

In general, all new non-wood transmission lines should be designed to allow for live-line maintenance work. Live-line techniques are PG&E’s preferred maintenance method for transmission lines. Electrical clearances for barehand work are described in the Electric Transmission Live-Line Barehand Work Procedures Manual. In designing for barehand work, it is important to work with transmission line specialist(s) on the clearances because the requirements may vary depending on the structure type, conductor configuration, and access.

For antenna installations on towers, minimum clearances are per Cal/OSHA, Section 2946, Table 1. The antenna and its support are considered to be part of the tower. CPUC *G.O. 95* electrical clearances are not the limiting factor.

In addition, all new, reconstructed, and/or re-permitted transmission structures that are located in raptor **high-risk areas** must be designed and constructed to be raptor-safe in accordance with the specifications found in the Edison Electric Institute’s “Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006.”

1. For non-wood construction, with post insulators, use 115 kV insulators for 60-70 kV lines. For a raptor sensitive location, provide a minimum phase to ground vertical clearance of 41 inches **. Post insulator framing on wood or steel poles is excepted from this clearance requirement.

2. For transmission line transposition structures, reasonable attempts may be made to achieve the maximum clearance with reasonable efforts, such as using outrigger crossarms on a lattice tower, a two-structure configuration (rolling transposition) or using post insulator type construction for vertical drops. If the phase transposition can only be performed using a single structure, the recommended clearances do not apply.

3. In some cases, the use of suspension insulator jumpers may result in reduced raptor-safety electrical clearances. In such events, it may be possible to substitute post insulators in place of suspension insulator in vertical position. This may require modifications on a structure to accommodate the post insulators.

** Phase to ground spacing based on calculation using APLIC data. APLIC currently does not have a recommendation for transmission phase to ground spacing.

In case of an installation of a 60-70 or 115 kV line switches, it is not practical to achieve recommended clearance, so these switches are excepted from these clearance requirements.

Electrical Clearances (continued)

Right of Way Width

Determine the right of way width from the centerline for a single span by summing the following distances:

- Structure width from the centerline.
- Conductor and insulator swing under R/W loading conditions per Table 16.
- 6-foot buffer.

When determining the right of way width for an entire line, the practice is to use one width for the line and to base that width on a relatively long span within the line (not the longest span). Additional width shall then be added, as appropriate, for those spans that exceed this base span. For long canyon spans, if the minimum conductor height above ground exceeds 50 feet, do not expand the right of way width to accommodate the extra conductor sway.

For parallel transmission lines, determine the centerline separation by calculating the maximum clearance from the following criteria:

1. OSHA Clearance (required for the inside circuit of multiple-circuit corridors)
   - Structure width from the centerline.
   - Twice the OSHA Section 2946, Table 2 clearances.
   - Crane width (4 feet).
   - Crane movement (5 feet).
2. Circuit-to-Circuit Sway Clearance
   - Conductor and insulator swing under non-stagger loading conditions.
   - Minimum circuit−to−circuit electrical clearance under differential wind to meet requirements of Table 17
3. Stagger Limitations Clearance (where structures on adjacent lines are staggered)
   - Insulator and conductor swing under R/W loading condition.
   - Minimum circuit−to−steel electrical clearance.

Table 16 Right of Way Width Loading Conditions

Situation	Temperature (°F)	Ice (inches)	Wind (lbs./sq. ft.)	Time
Right of Way Width	60	0	8	Final

Table 17 Stagger Limitations Loading Conditions

Description	Loading Condition
No Stagger Figure 4, Circuit−to−Circuit (check both conditions)	60°F, 8#, Final vs. 60°F, 6#, Final 60°F, 2#, Final vs. 60°F, 0#, Final
Unlimited Stagger Figure 5, Phase−to−Structure	60°F, 8#, Final

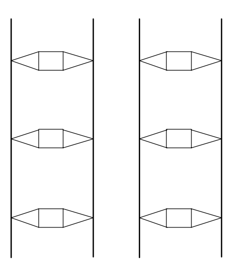

Figure 4
No Stagger
Circuit−to−Circuit

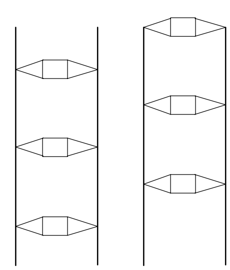

Figure 5
Unlimited Stagger
Phase−to−Structure

Joint Use Corridors

Transmission line right of ways should normally be clear of encumbrances such as above ground structures or underground pipelines. The unencumbered right of way is required to allow for proper maintenance of the transmission facility and to minimize any electric hazards. PG&E right of way widths are generally adequate to protect structures located outside the right of way boundary. Refer to Utility Procedure TD-1005P−03 on the use of PG&E lands and easements by others.

Induction Distance Criteria

- If the underground metal pipeline is outside the right of way, no action is required by PG&E.
- If the pipeline is within the right of way and parallel to the transmission line for more than 1 mile, a detailed induction analysis must be performed to assess the specific condition and, if required, to determine the proper mitigation.
- No action is required if the pipeline is not parallel to the transmission line.
- Special analysis is required for transmission lines located adjacent to railroads.

Arc Distance Criteria (parallel or perpendicular metallic pipeline crossings, etc.)

Avoid locating the concrete footing of a steel structure, any associated grounding systems, or the direct embedded portion of a steel or concrete structure closer than 25’ to any underground metal object or any pipeline containing combustible fluids. A typical underground metal object is defined as a pipeline or metallic foundation.

Site conditions may require that the minimum separation distance be increased to the arc distance ”D”, as determined by the following formula.

$D = 0.26\ (\rho J)^{1/2}$ where:

- “D” is the distance from the footing of a transmission structure to an underground metal object or pipeline containing combustible fluids in feet
- “ρ” is the average soil resistivity in ohm-meters
  - If the soil resistivity is known, use actual values
  - if unknown, use 100 ohm-meters for non-mountainous areas and 1000 ohm-meters for mountainous areas.
- “J” is the fault current in kA

If the arc distance “D” cannot be achieved using the above formula, us e detailed analysis techniques to provide specific mitigation. For all future projects, the safe distance cannot be reduced to less than 25’.

Above Ground Touch Hazards

No above ground metal objects (chain link fences, metal streetlights, metal sheds, etc.) should be within 8 feet of a steel or concrete structure.

Parallel Ties Between Circuits

For protection reasons, when paralleling two circuits on the same structure, maintain a minimum of six parallel ties between circuits between any two substations, and one tie every 5 miles for 25−mile or longer lines. Use a maximum of 11 equidistant ties for lines 50 miles or longer. For short lines, the requirement may be reduced after being examined on a case−by−case basis by system protection personnel.

Mitigation of Inductive Interference With Communication Lines (G.O. 52) Parallels

Every reasonable effort shall be made to avoid creating parallels with communication facilities. If the construction or reconstruction of a transmission line may create a parallel with a communication circuit, permission must be received from the communication companies to allow the parallel construction (G.O. 52, Rule IIb).

Transpositions

Transpositions can be installed on transmission lines to balance the capacitances to earth of their conductors. This equalizes the impedance of the three phases and minimizes inductive interferences with other lines. As a common practice, PG&E no longer installs transpositions on their transmission lines except for long lines. But, if a line longer than indicated below is contemplated, permission must be received from the communication companies in the area to omit transpositions (G.O. 52, Rule IIIc).

1. Horizontal single-circuit lines over 6 miles in length.
2. Triangular single-circuit lines over 12 miles in length.
3. Double-circuit lines over 9 miles in length.
4. If the line is in close proximity to multiple communication lines exceeding 1 mile in total length in each 10 consecutive miles of the transmission line.
5. If the line is in close proximity to one communication line exceeding 1 mile in total length in each 30 consecutive miles.

Close proximity is defined as separated from an existing communication line or highway where a future communication line may be constructed by less than 850 feet for 60 kV, and 1,000 feet for 115 kV and above. Crossings at angles over 30° are exempted from this requirement.
For 500 kV circuits, lines will be transposed to complete a barrel between terminals.

Transmission Line Switches

Transmission line switches shall be installed when required by transmission planning and/or system operations personnel. Before selecting the appropriate transmission line switch, a Line Switch Information Data Sheet must be completed and approved by system operations personnel.

Resistive glaze (RG) post insulators, as described in Document 067906, will be used in **all** insulation districts. Poles supporting switches should be increased by one pole class from the calculated pole class.

Table 18 Transmission Line Switch Standards and Guidelines

Title	Document
Line-Tension Type Air Switch Installation, 44-70 kV Pole Lines (For Reference Only)	048876
115 kV Pole-Mounted Switches	TD-1006S
Specifications for 115 kV Air Switch Poles	
115 kV Air Switch Pole, Miscellaneous Components	
Transmission Field Switch Operation Limitations	–
Installation of Switch Grounds on Steel Structures, 60-230 kV Transmission Lines	073443
Installation of Grounds on Wood Pole Transmission and Distribution Lines	021904
115 kV and 230 kV Line Switches Mounted on Transmission Structures	463236
Post-Type Apparatus Insulators	067906
Application of Aluminum Conductors and Connections for Substation Use	037788

Grounding Requirements

Electrical equipment and structures are grounded to eliminate potentially hazardous stray currents and/or voltages. For grounding requirements on wood poles, see Document 021904. For grounding steel structures, see Document 012566. For grounding fences, see Document 020607.

Grounding requirements for transmission line towers and poles inside the substation fence must be carefully designed. Treat these structures like any metallic structure inside the substation and conduct a specific analysis to determine the exact grounding requirements. If the structure is more than 8 feet outside the substation fence, then the structure should be independently grounded. If the structure is right up against or very close to the fence, conduct a specific grounding analysis. For grounding structures inside a substation fence, refer to Document 067910.

Overhead Ground Wire

Ground wires are installed on transmission lines to provide a path to ground for lightning strikes. This reduces the occurrence of lightning−related outages. Without overhead ground wires, a typical double−circuit, 230 kV tower line or single−circuit, 500 kV tower line will have approximately 5 outages/100 miles/year based on an isokeraunic level of 5 and a 25−ohm−footing resistance. This outage rate can be reduced to 1 outage/100 miles/year by the addition of two overhead ground wires.

In order to reduce power loss due to circulating induced current, the overhead ground wire on transmission lines greater than 2 miles in length should be insulated. When overhead ground wires are insulated, they are usually segmented into approximately 3−mile sections. Short lines, with a maximum length of 2 miles, shall be grounded.

Ground wire is normally required for:

- All high-capacity 230 kV lines.
- All 500 kV lines.
- In high isokeraunic level areas (5 strikes/year or greater).
- In close proximity to power plants (within 1 mile).
- In close proximity to 230 kV and 500 kV substations.

Short spans (less than 150 feet) into power plants and substations should not have a ground wire installed.

Fiberoptic Communication Cable (FOCC)

FOCC is optical ground wire (OPGW) or all dielectric self-supporting cable (ADSS). Minimum allowable electrical clearance requirements for FOCC are shown in Document 470591, Case 14.

When FOCC is in the overhead ground wire position, midspan separation between the FOCC and phase conductors is normally ensured by keeping the sag of the FOCC at 60°F, initial, 0# wind, sag to 80% of the phase conductor sag under the same conditions. Radial clearances should also be checked on steep incline spans and for differential ice loading conditions, when applicable.
On new structures, install OPGW to provide maximum 30° shielding angle to the phase conductor.

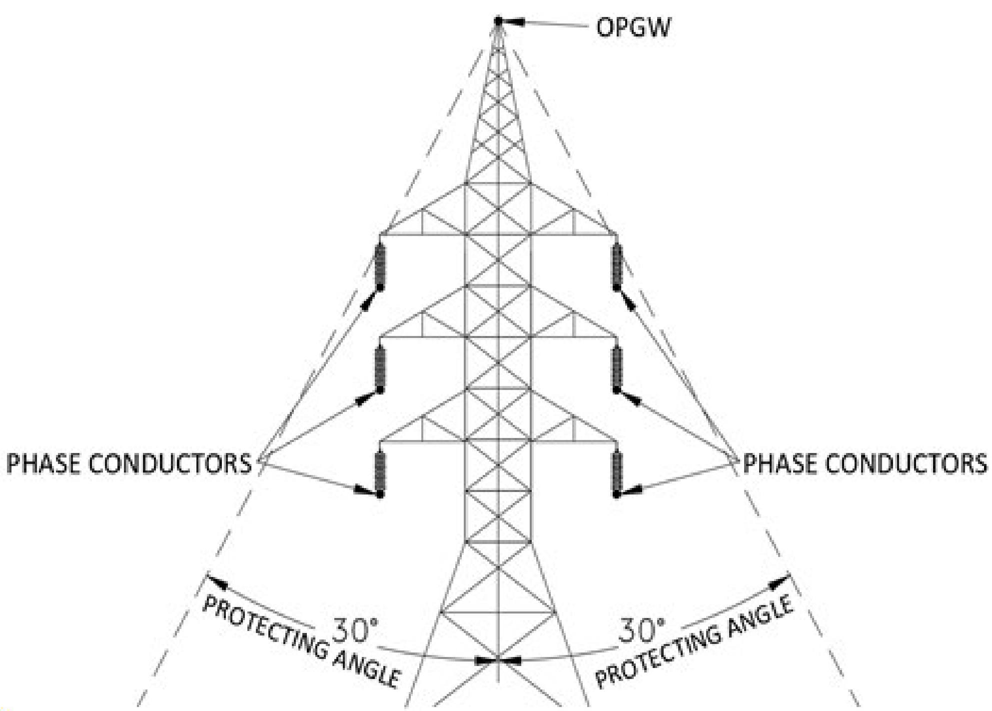

Figure 6
Shielding Angle

When ADSS fiberoptic cable is installed on transmission systems 115 kV and greater, the mounting location of the ADSS in relation to the phase conductors should be submitted to the cable manufacturer in order to perform an electric stress analysis. This is to determine if the electrical field strength exceeds the cable specifications and to evaluate if corona control is needed.

Table 19 Clearances for OPGW and ADSS in the Underbuild Position at 130°F, Final

Description	Rebuild	New Lines
FOCC Over Ground (urban areas)	18 ft.	20 ft.
FOCC Over Railway Track (not operated by overhead contact wires)	25 ft.	27 ft.
FOCC Over Railway Track (operated by overhead trolleys)	26 ft.	28 ft.
Distance of Conductor From Centerline of Pole (whether attached or unattached)	15 in.	15 in.
Distance of Conductor From the Surface of the Pole	3 in.	3 in.

OPGW fiberoptic cable on steel structures should be grounded at all structures via a ground strap.
Exception: OPGW installed on the 500 kV and some 230 kV systems are segmented similar to overhead ground wire installations on the 500 kV system. The OPGW on these lines is grounded at starting location, then the OPGW is insulated for approximately three miles, and open ended at the end of the 3 mile section. For the next run, the OPGW is then grounded at the tower location, then insulated for the next 3 miles, then open ended, etc. All conductive cable material (steel jacket and central core, if conductive) should be stripped beyond this point on the cable so that the remaining cable, when extended for splicing, is entirely non−conductive.

For fiberoptic cable installed at the distribution level, refer to Document 062719A for design and construction information.

Standard Material and Construction

All material and construction configurations shall meet PG&E standards as outlined in PG&E's Electric Overhead Construction Manual and the *Transmission Line Standards Manual*.

The standard type conductor used by PG&E is shown is Document 059626*.* The standard conductor purchase should specify specular conductor. Non−specular conductor should only be purchased if required for environmental mitigation. AAC type conductor is the first option where optimal for new construction. For bundled conductor construction, subconductor separation shall be 18 inches.

The aluminum strands in ACSS conductor are soft by design. As a result, in high wind areas, jumper loops and long vertical drops are subject to strand damage caused by low frequency oscillation. To minimize strand damage, install jumper strings to reduce the amplitude of conductor movement.

The preferred conductors for new construction are AAC and ACSR type conductors. The most economic conductor size shall be selected. AAC and ACSR conductors are expected to have a longer service life than ACSS type conductor. ACSS may be used for new or rebuilt lines provided the following conditions are met. All new structures must be designed to safely support the next larger ACSS conductor than the one size proposed. In other words, for 477 kcmil ACSS, the structures must be able to support and provide electrical clearances for 795 kcmil ACSS conductor. Otherwise, use AAC or ACSR conductor. ACSS is an acceptable conductor for use when reconductoring existing tower or tubular steel pole circuits.

Aluminum Conductor Composite Reinforced (ACCR) is a high temperature, low sag conductor that is exclusively manufactured by the 3M Company. One of the features of their proprietary core wire is that it is very light and made of inorganic material. The core wire¿s light weight, improved thermal expansion, aluminum zirconium outer strand wires allow the conductor to run at elevated temperatures for larger ampacity, while reducing the associated conductor sag considerably. This reduced sag is critical for transmission line applications as it reduces and in many cases eliminates, the need to raise transmission structures, as most line reconductoring projects involve high ampacity conductors generally require large number of steel structure modifications, both reinforcing for higher strength (due to the need to increase line tensions) and increasing the structure height (in order to address the increasing sags resulting from using the higher ampacity conductor).

- In particular due to the age for a large number of steel structures used on the PG&E transmission system, increasing line ampacity without creating additional burden for these structures (by not having to significantly increase the line tension) is very desirable to maintaining the life for these aging steel structures. Reducing work on the existing steel structures also aids in permitting since visual impacts are reduced (since the structures are not being replaced or raised) and environmental impacts due to reducing ground disturbances (since construction for the steel structure is reduced) thus helping when dealing with various agencies involved in granting PG&E permits to upgrade the transmission line.
- It is recommended that when this conductor is used for a transmission project that order of magnitude costs are developed with another conductor option, particularly ACSS, factoring in the additional steel structure work required to accommodate the increase conductor SAG from ACSS. The additional construction cost should offset the higher material price for the ACCR conductor. In addition, permitting cost should be reduced as the permitting costs increase with increased ground disturbances resulting from the additional construction work required for raising and modifying the larger number of steel structures required to install ACSS.

Vibration dampers should be installed on all non−ACSS conductor as specified in Document 015073. Dampers are generally not installed on ACSS conductors. For spans 1,800 feet or longer, contact the manufacturer to determine if the specific conditions require pre−stressing the ACSS conductor during installation. The pre−stress condition shall be held for 10 minutes.

All new and rebuilt towers must be evaluated for climbing guards, marking, and stepping per Utility Procedure TD−1009S will be used during the design process for new and reconstructed facilities (including reconductor projects) to determine if guarding is required.

Antennas may be installed on transmission structures. If possible, the antenna should not be located on the first structure outside the substation (the terminal dead−end structure).

The structure design criteria for 115 kV tubular steel poles is described in Document 051742.

Transmission Line Compliance Commitments and Design Requirements

The following is a list of compliance commitments for the design and construction of transmission lines.

CPUC Regulatory Requirements

- *G.O. 95* – “Rules for Overhead Electric Line Construction”
- *G.O. 128* – “Rules for Construction of Underground Electric Supply and Communication Systems”
- G.O. 26–D – “Regulations Governing Clearances on Railroads and Street Railroads with Reference to Side and Overhead Structures, Parallel Tracks, Crossings of Public Roads, Highways and Streets”
- G.O. 131D – “Rules Relating to the Planning and Construction of Electric Generation, Transmission/Power/Distribution Line Facilities”
- G.O. 52 – “Construction and Operation of Power and Communication Lines for the Prevention or Mitigation of Inductive Interference”

PG&E Design Requirements

- Document 470591 “Electrical Clearances for 60 kV, 70 kV, 115 kV, and 230 kV Overhead Transmission Lines”
- *Electric Overhead Construction Manual*
- *Transmission Line Standards Manuals* 1 and 2
- Transmission Line EMF Guidelines (PG&E)
- *Transmission Line Engineering Manual*
- *Transmission Line Design Manual*
- *Utility Operations Policies, Standards, and Guidelines*
- Utility Procedure TD-1008P-02 – “Overhead Transmission Line Naming and Line Numbering”
- Utility Procedure TD-1008P-03 – “Numbering Overhead Transmission Line Structures”
- Utility Procedure TD–1009S – “Requirements for Marking, Guarding, and Stepping of T&D Towers and Lattice Steel Poles”
- Civil Design Criteria Memorandum - DCM CST-04

Other Requirements

- Cal/OSHA Division of Occupational Safety and Health, Chapter 4, Subchapter 5, Group 2, Article 37– “Provisions for Preventing Accidents Due to Proximity to Overhead Lines”
- FAA Title 14, Code of Federal Regulations (14 CFR), Part 77– “Objects Affecting Navigable Airspace”
- FAA Order 8260 - “U.S. Standard for Terminal Instrument Procedures (TERPS)”
- FCC Title 47, Code of Federal Regulations (47 CFR), Telecommunication, Chapter I, Part 15 “Radio Frequency Devices”
- *Suggested Practices for Avian Protection on Power Lines*: The State of the Art in 2006 (EEI)
- *Mitigating Bird Collisions With Power Lines*: The State of the Art in 1994 (EEI)

Other References

- National Electric Safety Code - 2002 (or most recent revision)
- CPUC *General Order (G.O.) 95* - 2007 (http://WWW.CPUC.CA.Gov/Published/Graphics/655.pdf)
- Cal/OSHA, Title 8, Chapter 4, Subchapter 5 (http://WWW.Dir.CA.Gov/Samples/Search/Query.htm)

Revision Notes

Revision 14 has the following changes:

1. Changed document's owner.
2. Update table of contents.
3. Edited Notes 1, 4 and sentence "Where 60−70 kV circuits are…and substation engineering personnel." on Page 3.
4. Edited "Structural Requirements" paragraph on Page 3.
5. Edited "Decision Matrix for Light Duty vs. Tubular Steel Poles (TSP)" on Page 3.
6. Corrected and Edited Table 1 on Page 4. Edited Footnotes 4 and 5, and add Footnote 6 on Page 4.
7. Added "or PLS−CADD" to paragraph, "The minimum pole class…" on Page 4.
8. Edit paragraphs and add Table 4 to Page 5.
9. Corrected "Insulation Criteria" paragraph on Page 5.
10. Edit and rearrange bullet points on Page 6.
11. Changed "Rule 47.3" to "Rule 42", add note for California high speed rail and edited Figure 1 on Page 7.
12. Edited paragraph after Table 6 on Page 9.
13. Edit second paragraph of "Extreme Wind Loading Criteria" section and add ACCR to Table 7 on Page 10.
14. Added header "Engineered Steel and Other Non−Wood Pole Transmission (TSP, Engineered Direct Embed Pole, Towers, etc...) (continued)" to Pages 11 and 12.
15. Add "Open Jumper" section on Page 12.
16. Edit and rearrange bullet points on Page 13.
17. Add ACCR to Table 11 on Page 14.
18. Edited Footnotes 2 and 3 for Table 15 on Page 16.
19. Edit second bullet in "Right of Way Width" section and second bullet in "Circuit−to−Circuit Sway Clearance" section on Page 17.
20. Corrected Table 17 and add Figure 4 and Figure 5 on Page 17.
21. Update first paragraph and first bullet point in "Arc Distance Criteria (parallel or perpendicular metallic pipeline crossings, etc)" section on Page 18.
22. Add Figure 6 on Page 20.
23. Add "Aluminum Conductor Composite Reinforced" section on Page 22.