Appendix 2: Selected Regional Transmission Line Design Parameters

Conductors must be selected with sufficient thermal capability to meet continuous and emergency current ratings. The overhead line conductor and static wire should be chosen from those used by the Transmission Owner. This provides the ability to quickly repair a section of line with utility stock material should an emergency arise. Standard transmission conductor types are ACSR, ACSR/AW, ACSS, and ACAR. The ambient temperature range listed covers the system and is used for the electrical ratings of the conductors as well as the structural loads upon the towers or poles.

Wind Pressure: The pressure resulting from the exposure of a surface to wind. The pressure values provided are for wind acting upon objects with circular cross section. Pressure adjustments for other shapes shall be as set forth by the ASCE Guidelines for Electrical Transmission Line Structural Loading (ASCE Publication 74) [ASCE 74].

Radial Ice: Radial ice is an equal thickness of ice applied about the circumference of the conductors and static wires. Ice density is assumed to be 57 lbs per cubic foot. For the purpose of transmission line design, ice is not applied to the surface of the structure, insulators, or line hardware.

Temperature: Used for calculating conductor and static wire sag and tension.

Transverse load: Forces or pressures acting perpendicular to the direction of the line. For angle structures, the transverse direction is parallel to the bisector of the angle of the transmission centerline.

Longitudinal load: Forces or pressures acting parallel to the direction of the line. For angle structures, the longitudinal direction is perpendicular to the bisector of the angle of the transmission centerline.

All wires intact: A condition where all intended spans of conductors and static wires are assumed to be in place. In the case of a Line Termination Structure, conductor and static wire spans are only on one side of the structure.

Broken Conductor or Static Wire: A condition where one or more conductors or static wires are specified as broken. It is assumed that the broken conductor or static wire is in place on one side of the tower, and is removed from the other side. The span length for determination of loads from the conductor or static wire weight, wind pressure, and radial ice shall be not less than 60% of the design span length for the intact condition.

Load Factor: A value by which calculated loads are multiplied in order of provide increased structural reliability. For the purpose of structural design, Overload Capacity Factors as specified by NESC shall be considered Load Factors.
Design Loading Conditions

*NESC:* The provisions of the NESC Heavy Loading District, Class B Construction shall apply to all structure types. All wires intact. The latest NESC edition in effect at the time of line design shall apply. For informational purposes, the 1997 edition of NESC specifies the following requirements. Wind pressure – 4psf. Radial Ice – 0.5in.

*Temperature:* 0°F ~ For the purpose of calculating conductor or static wire tensions, a load constant of 0.3lbs shall be added to the resultant of the per linear foot weight, wind, and ice loads on the conductor or static wire. For steel structures, the load factor for wind load is 2.50; the load factor for vertical loads (dead weight and ice) is 1.50; and the load factor for conductor and static wire tension is 1.65. The associated factors for wooden transmission line structures shall be obtained from the Transmission Owner.

*Extreme Wind Loading Condition:* Applies to all structure types. All wires intact.

- *Line voltage 230kV and greater:* Wind pressure applied to the wires shall be 25psf. The ambient temperature is to be 60°F. The wind pressure applied to the structure shall be 31.25psf. Load factor is 1.00.
- *Line voltage less than 230kV:* The provisions of the NESC Extreme Wind loading shall be applied, subject to a minimum wind pressure of 17psf. The load factor is 1.00. The provision in NESC permitting exclusion of structures less than 60ft in height from extreme wind criteria shall not apply.

*Heavy Ice Loading Condition:* Applies to all structure types. All wires intact.

- *Line voltage 230kV and greater:* Radial ice thickness on the wires only is to be 1.50in. No wind pressure. Temperature is 32°F. Load factor is 1.00.
- *Line voltage less than 230kV:* Heavy ice loading (if any) shall be as specified by the Transmission Owner. Ice loading will not be more severe than that required for voltages 230kV or greater.

*Foundation Loading:* The ultimate strength of overturning moment and uplift foundations shall be not less than 1.25 times the design factored load reactions of the structure. The ultimate strength of foundations subjected to primarily compression load shall be not less than 1.10 times the design factored load reactions of the structure. Overturning moment foundations designed by rotation or pier deflection performance criteria shall use unfactored structure reactions for determination of the foundation performance, but shall use factored reactions for the 1.25 time ultimate strength check.

*Personnel Support Loading:* Structures shall be designed to support a point load of 350 lb at any point where a construction or maintenance person could stand or otherwise be supported.

**ELECTRICAL DESIGN PARAMETERS**

**Right-of-Way Width**

The transmission line is to be designed with adequate right-of-way width to provide access for line maintenance, repair, and vegetation management. These widths are based upon the listed number of circuits on the right-of-way. For additional circuits, a wider right-of-way should be utilized. Vehicle or other means of access to each structure site is required for both construction and maintenance activities.
Wire to Ground Clearance

The minimum allowed clearance between the lowest transmission line conductor(s) shall meet the required NESC minimum plus a safety envelope of 3 feet. (The safety envelope is required to allow for sag and clearance uncertainties due to: actual conductor operating temperature, conductor sagging error, ground topography accuracy, plotting accuracy and other sources of error. The inclusion of a safety envelope is considered to be prudent). The NESC minimum shall be calculated with the conductor at maximum operating voltage and the maximum operating temperature or maximum conductor loading. The minimum clearances should take into account the limitation of a 5 mA shock current as given in NESC Rule 232D3c. All areas beneath the line shall be assumed to allow vehicle access beneath the line. For agricultural areas that may utilize farming equipment, additional clearance will be provided to assure public safety and line reliability during the periods of farming and harvesting activities.

Wire to Signs, Structures, under the Wires

The minimum allowed clearance between the lowest transmission line conductor(s) shall meet the required NESC minimum plus a safety envelope of 3 feet. The NESC minimum shall be calculated with the conductor at maximum operating voltage and the maximum operating temperature.

Wire to Structure Clearances

The minimum clearances between the phase conductors and the supporting tower or pole shall not be less than specified. These clearances are to apply for all anticipated conductor positions from an every day condition to a displaced condition due to a 9-psf wind or ice loading. These clearances do not have any adders provided for birds or other animals, but are based upon the switching surge values.

Wire-to-Wire Clearances

Clearance between the bottom transmission conductor and any lower wire shall meet the required clearance of NESC Rule 233 and 235 as a minimum. When the lower wire is a non transmission wire, then the clearance should be at least 10 feet for voltages less than or equal to 230 kV, and 20 feet for voltages above 230 kV. This will allow safe personnel access to the non-transmission conductors. These clearances should be calculated with the transmission conductor at maximum operating temperatures or heavy ice, whichever provides greater conductor sag, and the non-transmission conductor at 0°F. Clearances between transmission conductors should be either the larger of clearances based upon switching surges, or clearances based on the NESC.

Line Design

For transmission conductors of different circuits, the clearances should be increased so that any wind induced dynamic conductor movement does not result in any breaker operations and subsequent reduction in transmission circuit reliability.
Conductor Operating Temperature and Conductor Sag

The conductor will be assumed to operate at or above the minimum temperature shown below, and at temperatures less than the maximum shown below. While the line conductor may be designed to operate at a lower temperature, the line must be sagged assuming the conductor temperature is at or above the minimum shown. For designed operating temperatures above the minimum shown, and still below the maximum, the line sag and clearances will be calculated for that operating temperature after rounding up to the nearest 10°C.

Insulation Requirements

The insulation system for the transmission line shall have values in excess of the leakage distance, 60 Hz wet, and Critical Impulse flashover. These values shown are minimum conditions and may need to be increased in specific locations such as coastal environments, industrial smokestack sites, or high altitudes.

Lightning Performance and Grounding

All transmission structures will be individually grounded through a dedicated earth driven grounding system composed of ground rods and/or buried counterpoise. This system is to be measured on each individual structure prior to the installation of any overhead conductors or wires. The maximum acceptable resistance measurement of this grounding system for voltages up to and including 230 kV is 25 Ohms, and 15 ohms for voltages 345 kV and greater. The grounding system may include radial counterpoise wires, Equipotentiality rings, or both. The Transmission Owner must approve all grounding methods, and connections to the grounding system that are below grade. These resistance requirements are to assure acceptable lightning performance on the line as well as provide for the safe grounding of the line by construction and maintenance forces. Individual tower grounding measurements will be allowed to exceed the 25 or 15 Ohms required only if the average value for the 5 adjacent structures along the line is less than the 25 or 15-Ohm restriction. To assure acceptable lightning performance, a shield wire is required above each transmission line. Each new structure design is to be analyzed to determine that the line design and actual grounding design provides the required lightning performance. In instances where it is very difficult to provide the required lightning performance, the Transmission Owner may grant permission to utilize a limited application of transmission lines arresters. In no case will chemical ground treatments be allowed to improve structure grounding.

EMF, RFI, TVI, and Audible Noise

The transmission line system is to be designed so that radio and TV interference is just perceptible at the edge of the right-of-way. This is typically the case with radio signal to noise ratios above 20 db, and TV signal to noise ratios above 40 db. The achievement of this level of performance is more of a problem for lines above 230 kV, so a radio frequency survey and investigation should be performed to measure actual radio and TV signal strength and calculate the signal to noise ratio. Audible noise at the edge of the right-of-way should be calculated for the designed transmission line using wet conductor as the design
condition. The resultant noise level must not exceed the level limited by the state and local authorities. Typically the limitation is 55 dbA during the daylight hours, and 50 dbA at night. Electric and Magnetic Field (EMF) levels are to be calculated and compared to any state or local limits. Modifications are to be made through phasing, structure height, ground clearance, etc. to assure these limitations are met. If no specific limitations exist, the line should be designed to the level of EMF on and adjacent to the right-of-way. A typical example of such an effort is the appropriate choice of phasing on the right-of-way.

**Inductive Interference**

A study should be done to determine the inductive impact upon other utilities due to the power flow in the new transmission line. The power flow may induce unusual currents and voltages in magnetic and electrical conductors that run parallel to the transmission line.

When it is determined that the currents or voltages are being induced in nearby utilities or other facilities, the engineer for the new or modified line being constructed must take the appropriate corrective actions to eliminate or lower the currents or voltages to an acceptable level.