

2019 PLS-CADD Advanced Training and User Group

Vegetation Work Sites and Wildfire Risk Assessment

by

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Introduction

- Vegetation management of overhead transmission and distribution line corridors has been a major topic in our industry from many years.
- Tree contact with transmission lines is a leading cause of electric power outages
- Vegetation management practices are under ever increasing regulatory scrutiny

Introduction

- Texas experienced more than 4,000 power line caused wildfires in a 3 ½ year period around 2013¹
- Estimated about 5% of wildfires caused by power lines in California between 2007 and 2016 accounting for about 11% of total acres burned²
- Power lines were found to cause 5 of the 11 major fires of the 2009 Black Saturday Fires in Victoria, Australia³

¹ Texas Wildfire Mitigation Project (www.wildfiremitigation.tees.tamus.edu)

² Kousky, Greig, Lingle & Kunreuther, “Wildfire Costs in California: The Role of Electric Utilities” August 2018

³ Thompson, Christodoulou & Cronau, “Powerline failures scrutinized as potential cause of brushfire crisis” October 2013

Presentation Outline

- Discuss vegetation clearances to overhead transmission and distribution lines
- Demonstrate vegetation clearance calculations in PLS-CADD
 - Grow-in clearances
 - Fall-in clearances
- Demonstrate creation of clearance Work Sites and graphical representations of clearance areas

National Regulations

- Overhead transmission lines above 200kV or lower voltage lines designated by NERC or WECC fall under NERC FAC 003
- Most lines below 200kV fall under individual state regulatory policies and procedures
- RUS utilities fall under RUS regulations, including specific requirements of Bulletin 1724E-200

NERC FAC 003 Highlights

- Prevent vegetation encroachments:
 - Into the Minimum Vegetation Clearance Distance (MVCD)
 - Due to fall-in from inside the ROW
 - Due to blowing together of applicable lines and vegetation located inside the ROW
- Prevent vegetation encroachments that account for:
 - Movement of conductors under their rating and all rated electrical operating conditions

NERC FAC 003-04 MVCD

FAC-003-4 Transmission Vegetation Management

**FAC-003 — TABLE 2 — Minimum Vegetation Clearance Distances (MVCD)¹⁷
For Alternating Current Voltages (feet)**

(AC) Nominal System Voltage (kV) ¹⁸	(AC) Maximum System Voltage (kV) ¹⁹	MVCD (feet) Over sea level up to 500 ft	MVCD feet Over 500 ft up to 1000 ft	MVCD feet Over 1000 ft up to 2000 ft	MVCD feet Over 2000 ft up to 3000 ft	MVCD feet Over 3000 ft up to 4000 ft	MVCD feet Over 4000 ft up to 5000 ft	MVCD feet Over 5000 ft up to 6000 ft	MVCD feet Over 6000 ft up to 7000 ft	MVCD feet Over 7000 ft up to 8000 ft	MVCD feet Over 8000 ft up to 9000 ft	MVCD feet Over 9000 ft up to 10000 ft	MVCD feet Over 10000 ft up to 11000 ft	MVCD feet Over 11000 ft up to 12000 ft	MVCD feet Over 12000 ft up to 13000 ft	MVCD feet Over 13000 ft up to 14000 ft	MVCD feet Over 14000 ft up to 15000 ft
765	800	11.6ft	11.7ft	11.9ft	12.1ft	12.2ft	12.4ft	12.6ft	12.8ft	13.0ft	13.1ft	13.3ft	13.5ft	13.7ft	13.9ft	14.1ft	14.3ft
500	550	7.0ft	7.1ft	7.2ft	7.4ft	7.5ft	7.6ft	7.8ft	7.9ft	8.1ft	8.2ft	8.3ft	8.5ft	8.6ft	8.8ft	8.9ft	9.1ft
345	362 ¹⁹	4.3ft	4.3ft	4.4ft	4.5ft	4.6ft	4.7ft	4.8ft	4.9ft	5.0ft	5.1ft	5.2ft	5.3ft	5.4ft	5.5ft	5.6ft	5.7ft
287	302	5.2ft	5.3ft	5.4ft	5.5ft	5.6ft	5.7ft	5.8ft	5.9ft	6.1ft	6.2ft	6.3ft	6.4ft	6.5ft	6.6ft	6.8ft	6.9ft
230	242	4.0ft	4.1ft	4.2ft	4.3ft	4.3ft	4.4ft	4.5ft	4.6ft	4.7ft	4.8ft	4.9ft	5.0ft	5.1ft	5.2ft	5.3ft	5.4ft
161*	169	2.7ft	2.7ft	2.8ft	2.9ft	2.9ft	3.0ft	3.0ft	3.1ft	3.2ft	3.3ft	3.3ft	3.4ft	3.5ft	3.6ft	3.7ft	3.8ft
138*	145	2.3ft	2.3ft	2.4ft	2.4ft	2.5ft	2.5ft	2.6ft	2.7ft	2.7ft	2.8ft	2.8ft	2.9ft	3.0ft	3.0ft	3.1ft	3.2ft
115*	121	1.9ft	1.9ft	1.9ft	2.0ft	2.0ft	2.1ft	2.1ft	2.2ft	2.2ft	2.3ft	2.3ft	2.4ft	2.5ft	2.5ft	2.6ft	2.7ft
88*	100	1.5ft	1.5ft	1.6ft	1.6ft	1.7ft	1.7ft	1.8ft	1.8ft	1.8ft	1.9ft	1.9ft	2.0ft	2.0ft	2.1ft	2.2ft	2.2ft
69*	72	1.1ft	1.1ft	1.1ft	1.2ft	1.2ft	1.2ft	1.2ft	1.3ft	1.3ft	1.3ft	1.4ft	1.4ft	1.4ft	1.5ft	1.6ft	1.6ft

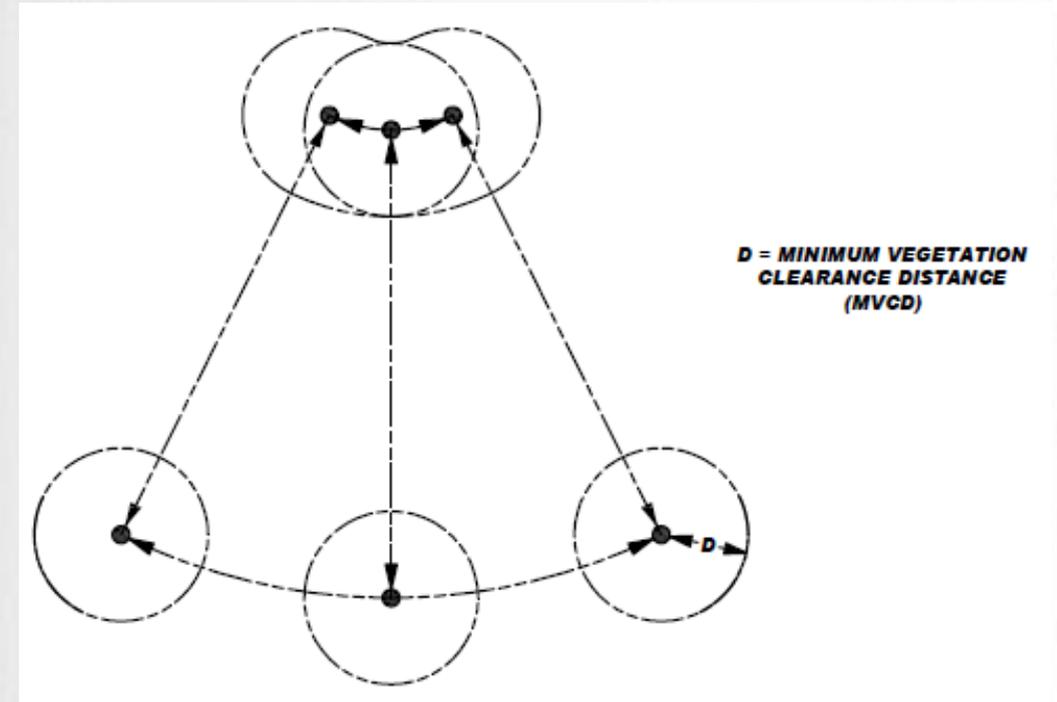
* Such lines are applicable to this standard only if PC has determined such per FAC-014 (refer to the Applicability Section above)

¹⁹ Table 2 – Table of MVCD values at a 1.0 gap factor (in U.S. customary units), which is located in the EPRI report filed with FERC on August 12, 2015. (The 14000-15000 foot values were subsequently provided by EPRI in an updated Table 2 on December 1, 2015, filed with the FAC-003-4 Petition at FERC)

¹⁷ The distances in this Table are the minimums required to prevent Flash-over; however prudent vegetation maintenance practices dictate that substantially greater distances will be achieved at time of vegetation maintenance.

¹⁸ Where applicable lines are operated at nominal voltages other than those listed, the applicable Transmission Owner or applicable Generator Owner should use the maximum system voltage to determine the appropriate clearance for that line.

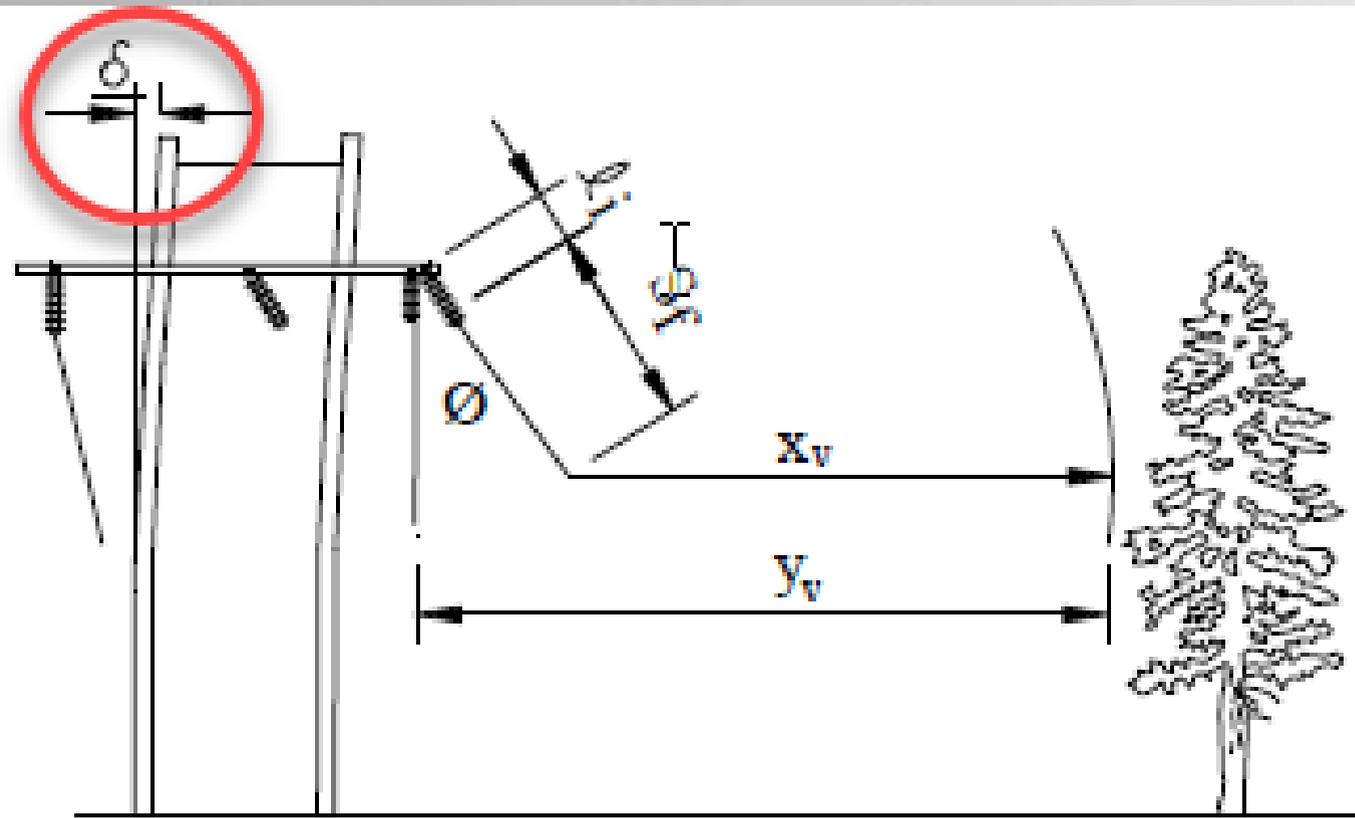
¹⁹ The change in transient overvoltage factors in the calculations are the driver in the decrease in MVCDs for voltages of 345 kV and above. Refer to pp.29-31 in the Supplemental Materials for additional information.



RUS 1724E-200 Highlights

- Applies to all lines 200kV and above or lower voltage lines designated as critical per NERC FAC 003
- Radial clearances provided and based on IEEE 516 Standard (Different than FAC 003-04)
- Clearances to be applied at all rated operating conditions
- Displacement of conductor to include movement of suspension insulators and deflection of flexible structures

RUS 1724E-200 Highlights



where:

- ϕ = conductor swing out angle in degrees under all rated operating conditions
- S_f = conductor final sag at all rated operating conditions
- x_v = radial clearance (include altitude correction if necessary)
- l_i = insulator string length ($l_i = 0$ for post insulators or restrained suspension insulators).
- y_v = horizontal clearance at the time of vegetation management work
- δ = structure deflection at all rated operating conditions

FIGURE 5-2: RADIAL CLEARANCE REQUIREMENT TO VEGETATION

RUS 1724E-200 Highlights

TABLE 5-2
RADIAL OPERATING CLEARANCES (in feet) FROM IEEE 516 FOR USE IN
DETERMINING CLEARANCES TO VEGETATION FROM CONDUCTORS
 (NERC Standard FAC-003.1 Transmission Vegetation Management Program, IEEE 516,
 Guideline For Maintenance Methods Of Energized Power Lines)

Conditions under which clearances apply:						
<p>Displaced by Wind: Radial operating clearances are to be applied at all rated operating conditions. The designer should determine applicable conductor temperature and wind conditions for all rated operating conditions. The displacement of the conductor is to include deflection of suspension insulators and deflection of flexible structures.</p> <p>The operating clearances shown are for the displaced conductors and do not provide for the horizontal distance required to account for blowout of the conductor and the insulator string. This distance is to be added to the required clearance. See Equation 5-1.</p> <p>Clearances are based on the Maximum Operating Voltage.</p>						
Nominal voltage, Phase to Phase, kV _{L-L}	34.5 & 46 ¹	69 ¹	115 ¹	138 ¹	161 ¹	230 ^{1,2}
Max. Operating Voltage, Phase to Phase, kV _{L-L}	----	72.5	120.8	144.9	169.1	241.5
Max. Operating Voltage, Phase to Ground, kV _{L-G}	----	41.8	69.7	83.7	97.6	139.4
Radial Table 5 IEEE Standard 516 Operating Clearances						
	Clearances in feet					
Operating clearance at all rated operating conditions	1.8	1.8	1.9	2.3	2.5	2.7
Design adder for survey and installation tolerance	1.5 feet for all voltages					
Design adder for vegetation	Determined by designer (see Note 3 below)					
<u>ALTITUDE CORRECTION TO BE ADDED TO VALUES ABOVE</u>						
Additional feet of clearance per 1000 feet of altitude above 3300 feet	.02	.02	.05	.07	.08	.12
Notes:						
1. These clearances apply to all transmission lines operated at 200 kV phase-to-phase and above and to any lower voltage lines designated as critical (refer to NERC FAC 003).						
2. The 230 kV clearance is based on 3.0 Per Unit switching surge.						
3. The design adder for vegetation, applied to conductors displaced by wind, should account for reasonably anticipated tree movement, species types and growth rates, species failure characteristics, and local climate and rainfall patterns. The design adder for vegetation, applied to conductors at rest, should account for worker approach distances in addition to the aforementioned factors.						

Vegetation Clearances in PLS-CADD

- Separate checks for Grow-in and Fall-in
- Simultaneously check up to 200 weather cases, including wind conditions (i.e. blowout)
- Wire positions including structure deflections can be calculated
- Group violations into Work Sites to easily identify clearing areas
- Create vegetation TIN and Work Site DXF/SHP files

Example Reports and Settings – Grow-In

- Select Grow-In analysis
- Select vegetation point feature code(s)
- Confirm clearances
- Confirm weather condition(s) for analysis
- Options available for range of structures, report info and graphical markers

The screenshot shows the 'Danger Tree Locator' software interface. The 'Vegetation Check' tab is active, and the 'Grow-In' section is highlighted with a red box. The 'Grow-In' section includes a checked checkbox for 'Check vegetation grow-in (violations displayed with square markers)', a color selection for 'Color for grow-in violation marker' (red), and radio buttons for 'Type of clearance requirement for Grow-In violations'. The 'Radial' option is selected. Below this, there is a note about required clearances. The 'Falling Tree' section is also visible, with a checkbox for 'Check clearance to falling trees (violations displayed with circular markers)', a color selection for 'Color for falling tree marker' (magenta), and input fields for 'Root ball radius (% of tree height)' (10), 'Clearance allowance (growth allowance PLUS electrical clearance) (ft)' (0), and 'Maximum horizontal distance between tree base and ground point for ground interpolation (ft)' (10). The 'Vegetation Feature Codes' section is also highlighted with a red box, showing a text field for 'Vegetation feature codes (other codes ignored): 3132...', buttons for 'Edit Feature Code Table (required clearances)' and 'Edit Criteria (weather cases considered)', and an input field for 'Horizontal distance from wire beyond which points should be ignored (ft)' (50). A note at the bottom explains that the command will consider all points within the specified horizontal distance to wires. The interface also includes 'OK' and 'Cancel' buttons at the bottom right.

Example Reports and Settings – Fall-In

- Select Falling Tree analysis
- Select vegetation point feature code(s)
- Confirm clearances
- Confirm weather condition(s) for analysis
- Options available for range of structures, report info and graphical markers

Danger Tree Locator

Vegetation Check | Structures and Circuits | Report and Markers | Work Site

Grow-In
 Check vegetation grow-in (violations displayed with square markers) Color for grow-in violation marker [Red]
Type of clearance requirement for Grow-In violations
 Rectangular: Must violate both horizontal and vertical clearance requirements to be a violation
 Radial: Is violation if total distance to wire is less than 'Req. Vert. Clear' from the feature code table.
Required horizontal and vertical or radial clearances are specified in the feature code table (edit using button at bottom of dialog). Required clearances should include grow-in allowances PLUS required electrical clearances.

Falling Tree
 Check clearance to falling trees (violations displayed with circular markers) Color for falling tree marker [Magenta]
Tree base assumed to have same X and Y as tree point with Z derived from TIN or closest ground point. Tree pivots about root ball edge which is the tree base shifted horizontally towards the wire by the root ball radius.
Violations are indicated when the arc swept by the falling tree contacts a wire.
Root ball radius (% of tree height) [10]
Clearance allowance (growth allowance PLUS electrical clearance) (ft) [0]
Tree height is based on height above ground. Ground elevation is computed from TIN. If tree is off edge of TIN then ground elevation is that of the closest ground XYZ point within the maximum horizontal distance below.
If program can't get ground elevation from TIN or closest ground point then falling tree will be reported as a questionable violation ('??') and marked with the color to the right. Color for falling tree with unknown ground [Yellow]
Maximum horizontal distance between tree base and ground point for ground interpolation (ft) [10]

Vegetation Feature Codes
Vegetation feature codes (other codes ignored): 3132...
[Edit Feature Code Table (required clearances)] [Edit Criteria (weather cases considered)]
Horizontal distance from wire beyond which points should be ignored (ft) [50]
Note: This command will consider all points within specified horizontal distance to wires. Points no longer need to be within the maximum profile offset defined in Terrain/Terrain Widths to be considered.
 Add optional concentrated load or ice to the span under consideration

[OK] [Cancel]

Including Structure Deflection in Calculations

- Can be used with Grow-In or Falling Tree analysis
- Structures must be modeled in PLS-POLE or TOWER
- Select either L3 or L4 analysis in *Criteria/SAPS Finite Element Sag-Tension*
- Then run the Grow-In or Falling Tree Analysis

SAPS Finite Element Sag-Tension

Selection below will affect type of model used when doing finite element sag-tension.

SAPS Analysis Level

L2 Finite element analysis of single section (no interaction between sections)
(sag-tension will take longer than for ruling span but still reasonably responsive)

L3 Finite element analysis of system of sections interconnected by stiffness matrices
(sag-tension computations will generally take a few seconds)

Level 3 options

Limit level 3 modeling to PLS-POLE structures, TOWER structures as level 2

L4 Finite element analysis of system of sections interconnected by full structure models
(sag-tension computations could take many minutes and use large amounts of RAM depending on the model)

Level 4 options

Limit level 4 modeling to PLS-POLE structures, TOWER structures as level 3

Limit level 4 modeling to guyed or otherwise asymmetrical structures

Strip joints/members that don't move significantly from level 4 TOWER models

Use Level 2 modeling for display and insulator swing calculations

Insulator Chaining Options

Include chained insulators in L2 and L3 models (always included in L4)

This setting applies in situations where a strain, suspension or 2-part insulator is suspended from the end of another suspension or 2 part insulator or swing bracket. It is provided in order to match results generated in earlier versions.

L2 and L3 FE sag-tension models in PLS-CADD 12.16 and earlier only include insulators that support wires. The flexibility or movement of other insulators that support these insulators is not accounted for (unless using L4).

Newer versions of PLS-CADD can include these insulators that support other insulators in the FE model and account for their movement.

Turn this feature on for the most accurate model possible on any new projects. Turn it off for projects with chained insulators and sections sagged or clipped in PLS-CADD 12.16 and earlier to match earlier tensions.

L3 and L4 Options for Structure Loads

Limit L3 and L4 structure modeling to structures within specified number of spans of structure having load computed. Remaining structures will be modeled L2.

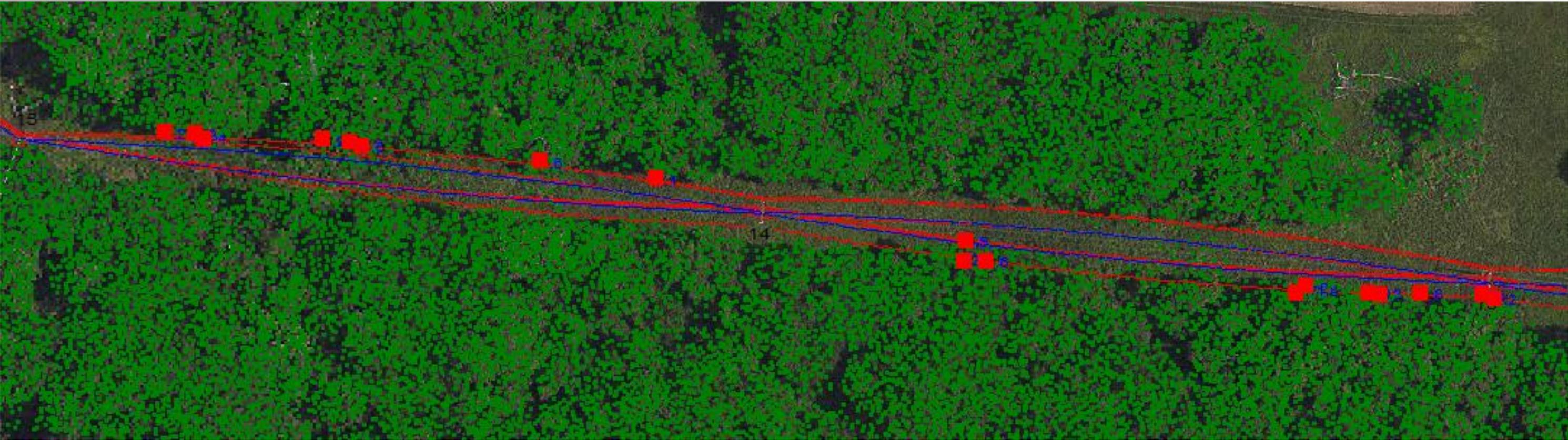
Number of spans out to extend L3/L4 structure modeling (0 if want only structure having its loads computed)

Jumper Options

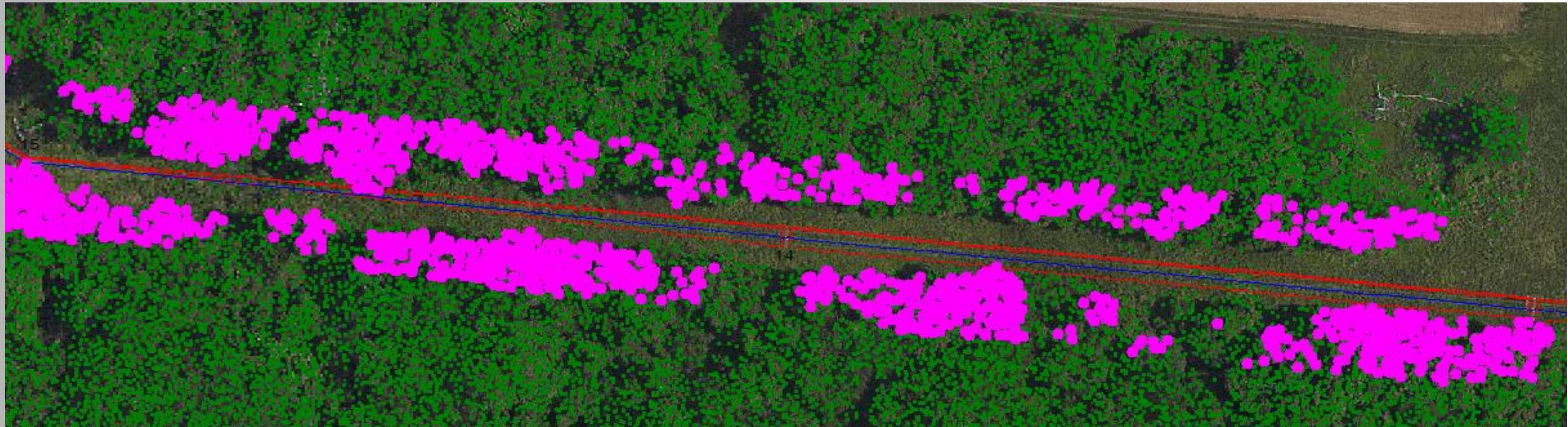
Include jumpers in FE sag-tension model: Note that for L2 this can triple analysis time as model grows from single target section to target section plus up to two sections it is jumped to. Minimal impact on L3 and L4.

OK Cancel

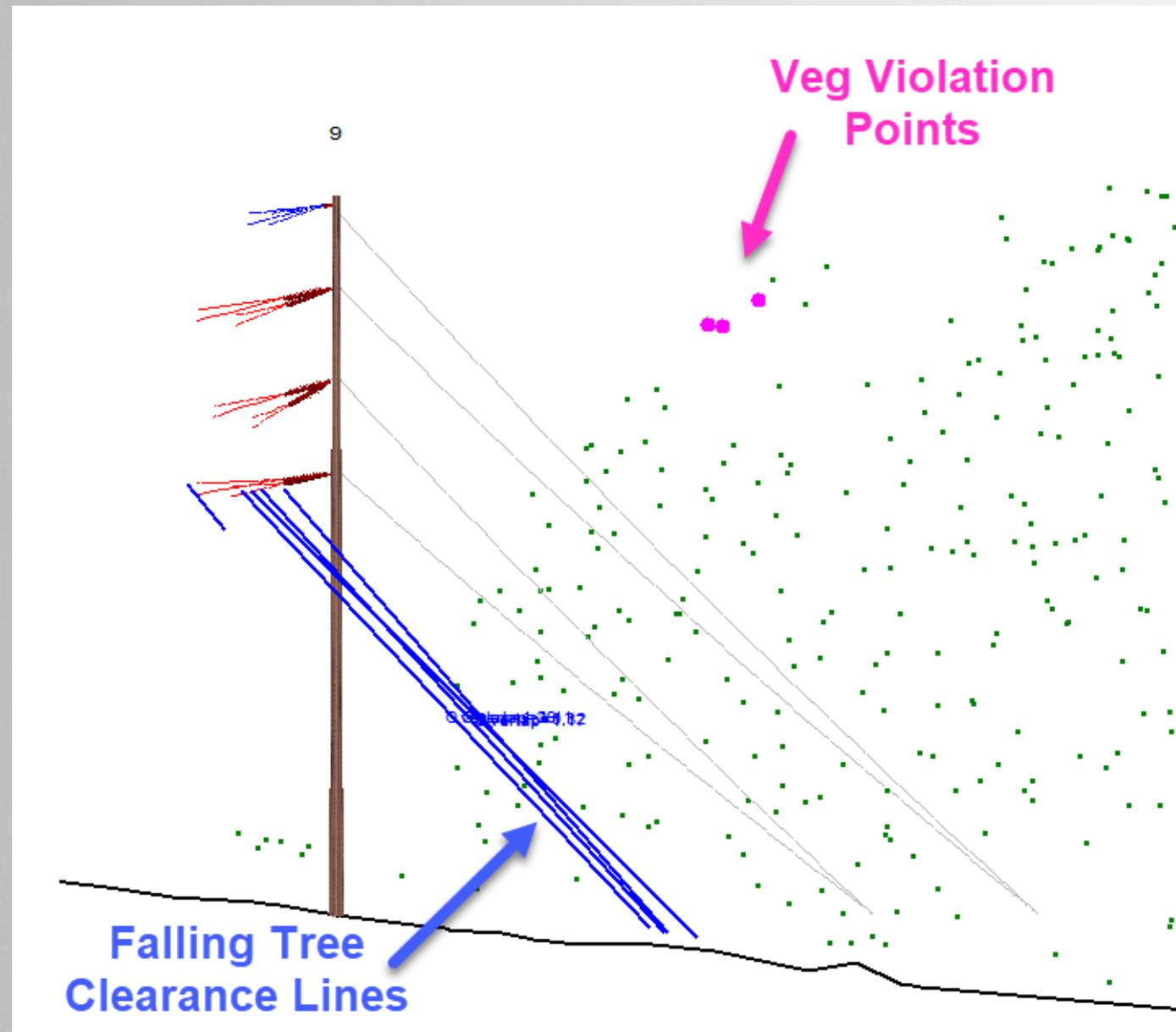
Plan View of Grow-In Violations under Wind Condition



Plan View of Falling Tree Violations under No Wind Condition



Cross Section View of Falling Tree Violations at Angle Structure



Example Reports and Settings – Work Sites

- Can be used with Grow-In or Falling Tree analysis
- Input work site size parameters
- Options available for TIN, KMZ/KML and SHP file creation
- Options available for range of structures, report info and graphical markers

Danger Tree Locator

Vegetation Check | Structures and Circuits | Report and Markers | **Work Site**

Enable work site feature (turn off to disable potentially show work site / centroid features)

Maximum separation between points within work site (ft) 100.00

Maximum work site size (0 to disable) (ft) 400.00

Draw marker labeling distance from centroid min. clear point to wire.

Draw markers indicating work site centroid and points associated with it

Draw markers indicating work site centroid perimeter (requires TIN creation)

Feature code for work site centroid point Do not create points

Z coordinate for centroid point

Z computed from TIN at work site centroid X and Y coordinates

Z of work site centroid

Zero

Veg violation TIN options

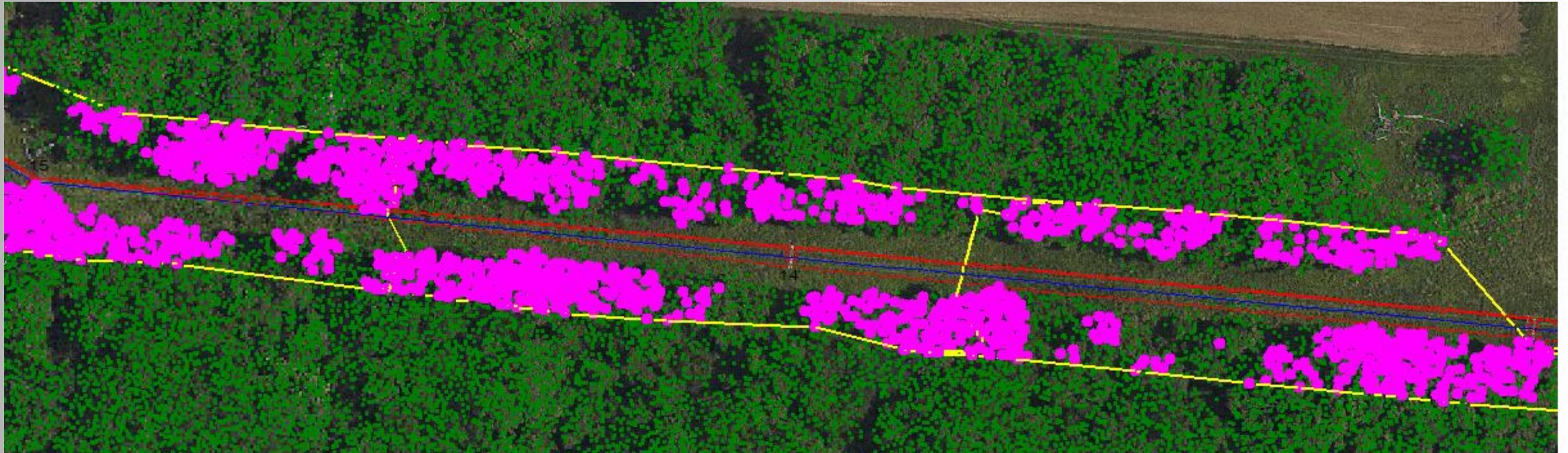
Create veg. violation TIN (alternate Z value will be distance to wire for use with isoline functions)

Save veg. violation TIN

Export as KMZ/KML (Rendered TIN - Google Earth) or SHP (Perimeter Only)

OK Cancel

Plan View of Work Sites for Falling Tree Violations



Power Line Systems

IT'S ALL ABOUT YOUR POWER LINES

Advanced Sag & Tension

IEC

FAC 008/009

NESC

Materials Management

LiDAR Modeling

Structural Analysis

PLS-CADD

CSA

Pole Analysis

CENELEC

Distribution

Transmission

NERC Ratings

Line Optimization

Questions?

Project Estimating

FAC 003

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Joint Use

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1000+ Users in 100+ Countries

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IEEE

Line Ratings

TOWER

Drafting