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Audible Noise Calculator in PLS-CADD

If you ever find yourself standing near a high voltage overhead line on a foggy day and you listen closely, you may hear a humming or crackling sound. This is corona induced audible noise coming from the overhead lines. This sound is caused by the electrical ionization of the air that occurs near the surface of the energized conductor due to very high electric field strength. Corona produced by an overhead line is a function of various factors including the voltage of the line, the conductor diameter, the local weather conditions, and other variables.

Corona discharge can contribute to energy losses. In response, many transmission lines are designed to minimize the corona audible noise. Corona typically becomes a design concern for transmission lines 230 kV and above and is less noticeable at lower voltage lines.

There are two types of audible noise produced by corona discharges:

- **broadband noise**, which is a high frequency sound.
- **the hum**, which is a pure tone frequency that is twice the power frequency.

Contributing Factors

The electric fields of overhead lines contribute to the creation of audible noise. Understanding the magnitude of the electric field and what can be done to reduce or better create uniformity in the fields is fundamental to reducing audible noise.

The electric field is greatest at the surface of the conductor. Generally, large-diameter conductors have lower electric field gradients at the surface of the conductor which leads to a lower corona than smaller conductors. Unevenness of the conductor's surface can also decrease the value of breakdown voltage. Thus, stranded conductors with irregular surfaces give rise to more corona than solid conductors.

The physical state of the atmosphere such as the pressure, temperature and humidity impacts the level of ionization of air molecules around an energized wire. Audible noise is worsened in wet weather like rain and fog as the water droplets on the conductor surface produce corona discharges. Corona also increases at higher elevations where the density of the atmosphere is less than at sea level.

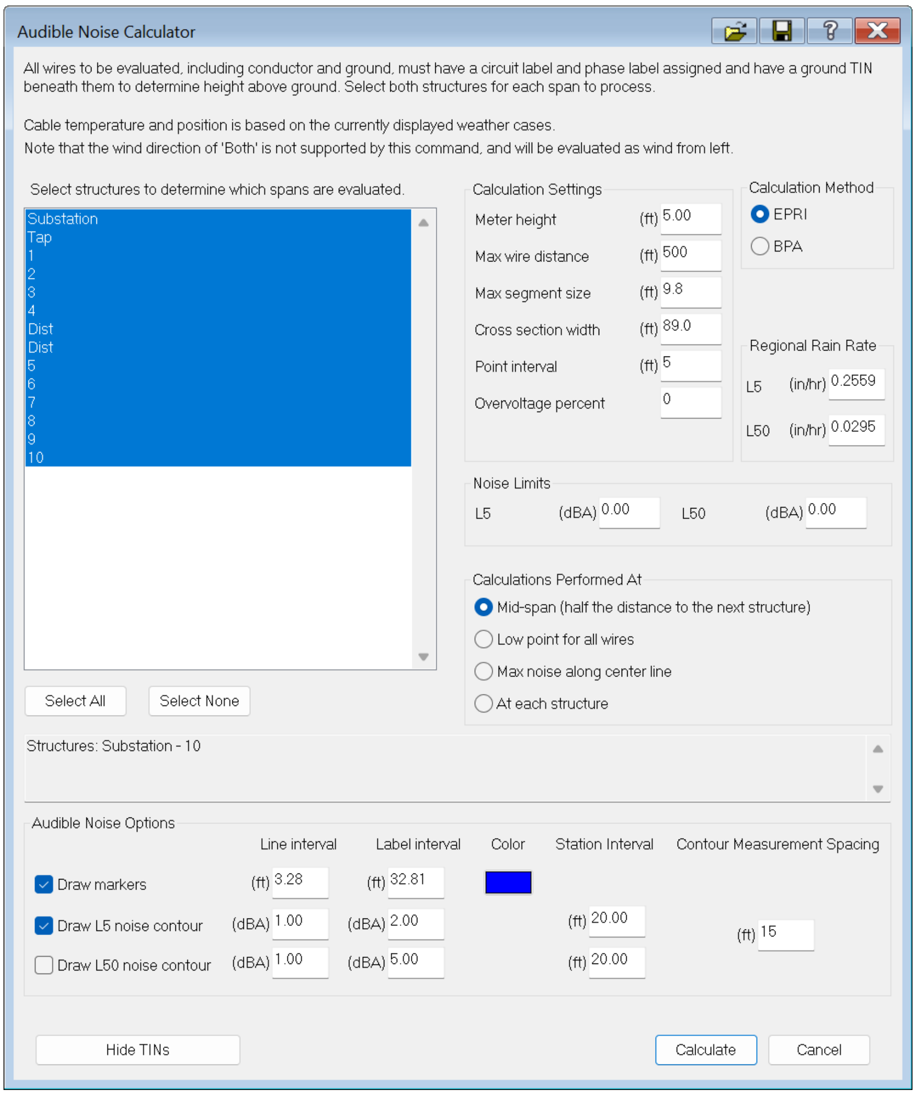
The condition of the conductor is also important. Any irregularities or damage on the conductor's surface or sharp edges on the hardware can concentrate the electric field at these locations. This can result in an increased electric field gradient at these spots and resulting in corona. Environmental factors can also contribute to corona. Pollution and dust can cause anomalies on the conductor surface and be a source for corona.

All these factors should be considered in the design of overhead lines when trying to reduce corona induced audible noise.

PLS-CADD Audible Noise Calculator

PLS-CADD can calculate the broadband noise component using either the *EPRI Method* or the *BPA Method* to calculate the Audible Noise as described in Section 11.2.15 of the **PLS-CADD** manual. This section of the manual describes each of the inputs in the dialog below. The **PLS-CADD** audible noise calculator can calculate noise during fair weather (dry), wet conductor (measurable natural rain or fog), or heavy rain conditions.

To use the Audible Noise calculator in **PLS-CADD** the user must have the circuit and phase label assigned to all wires and have a Ground TIN beneath the spans being considered. With the menu command **Sections/ Electric/ Audible Noise Calculator...** the software will run the Audible Noise calculator based on the settings entered in the Audible Noise Calculator dialog, shown below.



Upon completion of the analysis, the results from this calculator are sent to a report and graphical representation of the audible noise levels is available in the **PLS-CADD** model.

The Audible noise report is a text report that includes different reports regarding the audible noise calculations. The top of the Audible Noise Calculation Notes includes the inputs and options used for the calculations. The **Section Data for Audible Noise Results** provides the data for each cable used for the calculations. See a sample of this report below.

Audible Noise Calculation Notes:
1) Calculations based on the EPRI Red Book methods (3rd Edition, 2005 - 10.4 Calculation of Transmission-Line Audible Noise).
2) All wire positions are modeled at the specified weather case and wind direction. Height above ground determined by the modeled ground TIN.

Meter height above ground:	5.00 (ft)
Maximum wire distance:	500.00 (ft)
Maximum cable segment size:	9.80 (ft)
Cross section offset +/-:	89.00 (ft)
Result interval:	5.00 (ft)
L5 limit:	0.00 (dBA)
L50 limit:	0.00 (dBA)
Calculation Method:	EPRI
Rain Rate L5:	0.2559 (in/hr)
Rain Rate L50:	0.0295 (in/hr)
Contour Map Spacing:	15 (ft)
Analyzing spans between these structures:	Substation - 10

This feature is still experimental and has received only limited testing. Results should be carefully inspected. ??

One or more sections are missing phase labels. Phase angles for these sections are assigned automatically (1 = 0°, 2 = 120°, 3 = -120°) ??
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Section Data for Audible Noise Results:

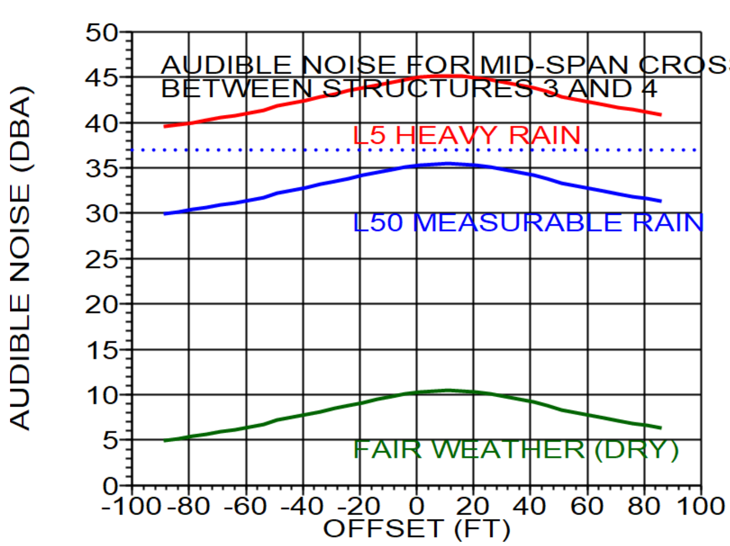
Section Number	Section Note	Voltage Ph-Ph (kV)	Current (Amps)	Cable Filename	Conductors Per Phase	Bundle Diameter (in)	Cable Radius (in)	Weather Case	Condition	Wind Dir.	WC Temperature (deg F)	Effective Radius (in)
1		0.0	0.0	OPGW-AP - 48U (3x24) - 17,2mm - 226kA2s - 79kN 1-1441.wir	1	0.000	0.338	Cold Uplift	Initial FE	Left	-5.000	0.338
2		0.0	0.0	OPGW-AP - 48U (3x24) - 17,2mm - 226kA2s - 79kN 1-1441.wir	1	0.000	0.338	Cold Uplift	Initial FE	Left	-5.000	0.338
3		12.0	1000.0	linnet	1	0.000	0.360	60 Deg F	Max Sag FE	Left	60.000	0.360
4		0.0	0.0	3no_6_alumoweld.wir	1	0.000	0.174	Cold Uplift	Initial FE	Left	-5.000	0.174
5		0.0	0.0	3no_6_alumoweld.wir	1	0.000	0.174	Cold Uplift	Initial FE	Left	-5.000	0.174
6		0.0	0.0	3no_6_alumoweld.wir	1	0.000	0.174	Cold Uplift	Initial FE	Left	-5.000	0.174
7		0.0	0.0	OPGW-AP - 48U (3x24) - 17,2mm - 226kA2s - 79kN 1-1441.wir	1	0.000	0.338	Cold Uplift	Initial FE	Left	-5.000	0.338
8		138.0	1000.0	DRAKE_ACSR_AW2_GCC.wir	1	0.000	0.554	Maximum Operating	Max Sag FE	Left	212.000	0.554
9		138.0	1000.0	DRAKE_ACSR_AW2_GCC.wir	1	0.000	0.554	Maximum Operating	Max Sag FE	Left	212.000	0.554
10		138.0	1000.0	DRAKE_ACSR_AW2_GCC.wir	1	0.000	0.554	Maximum Operating	Max Sag FE	Left	212.000	0.554
11		345.0	1000.0	CARDINAL_ACSR_AW2_GCC.wir	4	25.456	0.598	Maximum Operating	Max Sag FE	Left	212.000	8.380
12		345.0	1000.0	CARDINAL_ACSR_AW2_GCC.wir	4	25.456	0.598	Maximum Operating	Max Sag FE	Left	212.000	8.380
13		345.0	1000.0	CARDINAL_ACSR_AW2_GCC.wir	4	25.456	0.598	Maximum Operating	Max Sag FE	Left	212.000	8.380

Then there is a Summary of the maximum audible noise and the location at which it occurs in the section titled **Audible Noise Measurement Summary**. This provides audible noise levels for the three conditions per each span.

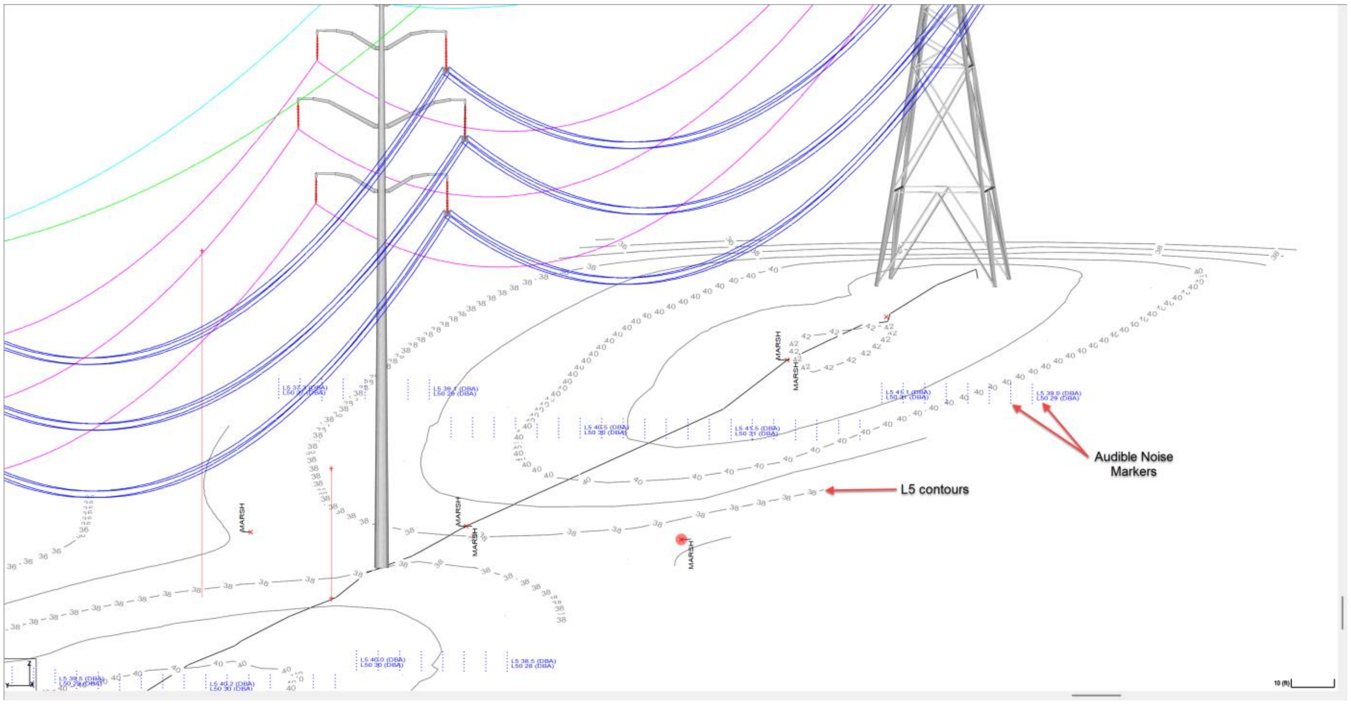
Audible Noise Measurement Summary:

Span#	Back Structure	Ahead Structure	Measurement X (ft)	Y (ft)	Z (ft)	Station (ft)	Offset (ft)	Audible Noise Max L5 (dBA)	L50 (dBA)	Fair Weather (dBA)
1	Substation	1	439.2	-11.0	1524.6	439.2	11.0	42.7	33.1	8.1
2	1	2	1239.8	-21.0	1490.5	1239.8	21.0	41.3	31.5	6.5
3	2	3	2072.8	-51.0	1461.2	2072.8	51.0	42.2	32.6	7.6
4	3	4	2456.1	-436.6	1434.7	2903.6	11.0	45.1	35.5	10.5
5	4	5	2461.1	-1247.3	1408.4	3714.4	6.0	43.6	33.8	8.8
6	5	6	2466.1	-2005.1	1410.4	4472.1	1.0	43.7	34.1	9.1
7	Dist	Dist	2464.5	-1249.1	1408.8	3716.2	2.6	43.5	33.8	8.8
8	6	7	2939.0	-2374.0	1382.3	5327.0	-14.0	42.8	33.2	8.2
9	7	8	4052.8	-2409.0	1298.6	6440.8	21.0	42.0	32.1	7.1
10	8	9	5168.0	-2409.0	1295.8	7556.0	21.0	40.2	29.9	4.9
11	9	10	6181.3	-2404.0	1292.0	8569.3	16.0	41.5	31.2	6.2
12	Tap	1	610.8	-51.0	1519.0	610.8	51.0	42.0	33.0	8.0

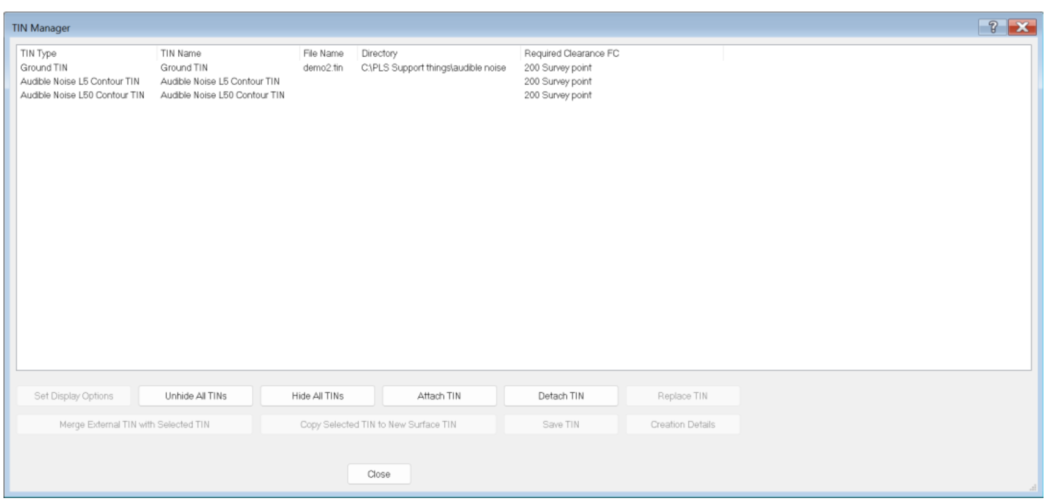
The cross-sectional results are also reported for each span or location in both a tabular and graphical form, with optional markers being drawn in the Plan or 3D Views, depending on the inputs. The graphical cross section shows the calculated results (solid lines) and the limits (dashed lines) for the three conditions.



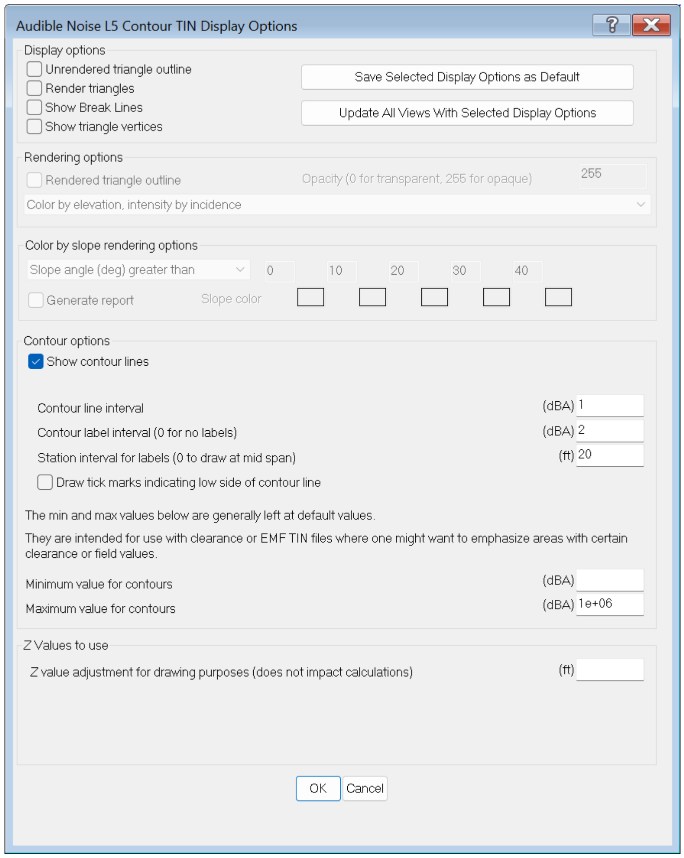
Results are also displayed graphically within the **PLS-CADD** model in Plan, 3D, and sheets views via markers and contour lines. The markers are displayed at the interval and color (blue below) specified in the Audible Noise Calculator dialog. *Markers in the PLS software are temporary and can be cleared with F5, saved, or reloaded*. The audible noise contours show a graphical representation of the noise levels along the overhead line right-of-way.



The audible noise results are also saved to a TIN. The menu command **Terrain/ TIN/ TIN Manager** in **PLS-CADD** allows users to see available TINs within a project. The image below shows the L5 and L50 audible noise contour TINs available in a project.



Selecting the L5 or L50 contour TINs and pressing the **Set Display Options** button allows the user to render the TIN in different ways, toggle on/off contours or update the way the contours are displayed, compared to the initially input data in the Audible Noise Calculator dialog.



All this information can help a **PLS-CADD** user understand the levels of corona induced audible noise a transmission line may produce. With **PLS-CADD,** users can make design choices to minimize the electric fields of overhead lines and reduce the corona induced audible noise for a transmission line.