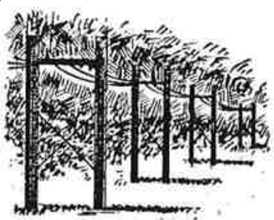
Electric Field Measurements for 345-kV Transmission Lines

David K. Bruening



Electric fields are produced by high voltage transmission lines. Because of concerns about the effects of electric fields on biological systems, and to improve the confidence level when estimating electric field strengths for Omaha Public Power District (OPPD) high voltage transmission lines, OPPD has measured the electric field strengths generated by its 345-kV 60-Hz transmission lines. This report details the results of those measurements.

Electric Field Measurements

Because electric field strengths are the greatest for transmission lines voltages of 345 kV and above, the measurements were limited to 345-kV, 60-Hz transmission lines. Since OPPD uses four basic types of 345-kV transmission configurations, the measurements were limited to these four structure types. Iowa State University, Department of Electrical Engineering, performed the electric field measurements.

Analysis of Results

The electric fields were measured for the four types of 345-kV structures: lattice tower, tubular H-frame, wooden H-frame, and single steel pole. Since computer programs are frequently used in transmission line design to estimate electric field strength, a computer program was used to calculate the electric fields for each of the tower types and the results were compared with the measured electric field strengths. Figures 1–4 are graphs of the electric field strengths vs. the distance from the center of the right of way (ROW) for the four types of structures. The figures contain both the measured electric field and computer calculated[1] electric field strength data. The width of the ROW for each type of structure is shown at the bottom of each figure. Tables 1–4 contain the data used to plot Figures 1–4. Tables also contain a statistical comparison of the measured and calculated electrical fields. The mean and the standard deviation for the percentage of difference between the measured and calculated electric field data demonstrate good agreement between measured and calculated data.

To compare the electric field strengths from the above four structure types at a common ground clearance, the electric field strengths were adjusted for a conductor design height of 31 feet. The minimal ground clearance for open fields allowed by the National Electrical Safety Code is 26.3 feet; however, 31 feet is used by OPPD as their minimal design clearance. Figure 5 is a graph of the maximal electric field strength on the ROW vs. conductor height for the four structure types, and Figure 6 is a graph of the electric field strength at the ROW edge vs. conductor height for the four structure types. In those instances where the electric field is nonsymmetric, the larger of the two ROW edge values is used.The vertical dashed line on Figures 5 and 6 represents the minimal 345-kV transmission line design clearance for open fields. Table 5 is a tabulation of the electric field strength as a function of phase conductor height. The field strength estimates are based on the assumption that the field varies inversely with height. Table 6 summarizes the electric field strength data (extrapolated from measured values) at a design phase conductor height of 31 feet.

Table 1. Electric Field Measurements, 345-kV Lattice Tower

Distance (feet)	Electric Field (kV/m)		Percentage of Difference[a]
	Measured	Calculated	
−90	0.9	0.834	7.33
−70	1.4	1.205	13.9
−60	1.6	1.386	13.4
−50	1.7	1.534	9.76
−40	1.9	1.664	12.42
−30	2.0	1.827	8.65
−20	2.2	2.047	6.95
−15	2.3	2.158	6.17
−10	2.4	2.251	6.21
−5	2.5	2.313	7.48
0	2.5	2.334	6.64
0	2.4	2.334	2.75
5	2.4	2.313	3.62
10	2.4	2.251	6.21
15	2.3	2.158	6.17
20	2.2	2.047	6.95
30	2.0	1.827	8.65
40	1.8	1.664	7.56
50	1.6	1.534	4.125
60	1.5	1.386	7.60
70	1.3	1.206	7.23
90	1.0	0.834	16.6

[a] [(Measured − calculated) ÷ measured] × 100. Average, 8.11; SD, ±3.55.

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Table 2. Electric Field Measurements, 345-kV Tubular H-Frame

Distance (feet)	Electric Field (kV/m)		Percentage of Difference[a]
	Measured	Calculated	
−90	0.4	0.397	0.750
−70	0.4	0.542	−35.5
−60	0.6	0.644	−10.7
−50	0.8	0.778	2.75
−40	0.8	0.969	−21.1
−30	1.2	1.248	−4.00
−20	1.7	1.646	3.18
−15	2.0	1.883	5.85
−10	2.2	2.124	3.45
−5	2.4	2.339	2.54
0	2.4	2.494	−3.92
0	2.6	2.494	4.08
5	2.8	2.565	8.39
10	2.8	2.564	8.43
15	2.8	2.550	8.93
20	2.8	2.606	6.93
30	3.2	2.941	8.09
40	3.3	3.070	6.97
50	2.9	2.732	5.79
60	2.3	2.165	5.87
70	1.7	1.617	4.88
90	0.9	0.869	3.44

[a] See Table 1 footnote. Average, 0.687; SD, ±10.7.

Discussion of Results

In the summary to "Biological Effects of 60-Hz Power Transmission Lines,"[2] the following was concluded, "The Commission unanimously believes that the scientific information now available supports the conclusion that it is unlikely that 60-Hz electric and magnetic fields associated with high voltage transmission lines has led, or can lead, to public health problems." The Commission further recommended adoption of transmission line guidelines that included criteria to limit nuisance shocks.

In regard to limiting nuisance shocks from electric fields on the ROW, Bonneville Power Administration has set maximal design electric field strengths at 5 kV/m, 3.5 kV/m, and 2.5 kV/m for road crossings, shopping center parking lots, and

Table 3. Electric Field Measurements, 345-kV Wooden H-Frame

Distance (feet)	Electric Field (kV/m)		Percentage of Difference[a]
	Measured	Calculated	
−90	1.0	1.113	−11.3
−70	2.0	1.867	6.65
−60	2.6	2.388	8.15
−50	3.3	2.934	11.1
−40	3.7	3.322	10.2
−30	3.6	3.274	9.06
−20	3.0	2.680	10.7
−15	2.5	2.266	9.36
−10	2.2	1.879	14.6
−5	1.9	1.604	15.6
0	1.9	1.504	20.8
0	1.8	1.504	16.4
5	1.8	1.604	10.9
10	2.1	1.879	10.5
15	2.8	2.266	19.1
20	3.0	2.680	10.7
30	2.7	3.274	11.5
40	3.7	3.322	10.2
50	3.2	2.934	8.31
60	2.6	2.388	8.15
70	2.0	1.867	6.65
90	1.2	1.113	7.25

[a] See Table 1 footnote. Average, 10.2; SD, ±6.14.

commercial/industrial parking lots, respectively.[3] By comparison, the maximal OPPD measured electric field strength was 4.6 kV/m, which occurred for the 345-kV single steel pole (Figure 4).

If the 345-kV lattice tower, wooden H-frame, or single steel pole conductors are reduced from existing height to 31 feet, the

Table 4. Electric Field Measurements, 345-kV Single Steel Pole

Distance (feet)	Electric Field (kV/m)		Percentage of Difference[a]
	Measured	Calculated	
−90	0.1	0.148	−48.0
−70	0.1	0.049	51.0
−60	0.2	0.215	−7.5
−50	0.8	0.534	33.25
−40	1.0	1.062	−6.2
−30	1.9	1.875	1.32
−20	3.0	2.969	1.03
−15	3.4	3.551	−4.44
−10	4.0	4.067	−1.68
−5	4.4	4.425	−0.57
0	4.6	4.546	1.17
0	4.4	4.546	−3.32
5	4.4	4.401	−0.023
10	4.2	4.023	4.21
15	3.6	3.494	2.94
20	3.0	2.904	3.20
30	1.8	1.813	−0.72
40	1.0	1.017	1.70
50	0.6	0.511	14.8
60	0.3	0.218	27.3
70	0.2	0.104	48.0
90	0.2	0.172	14.0

[a] See Table 1 footnote. Average, 5.82; SD, ±20.6.

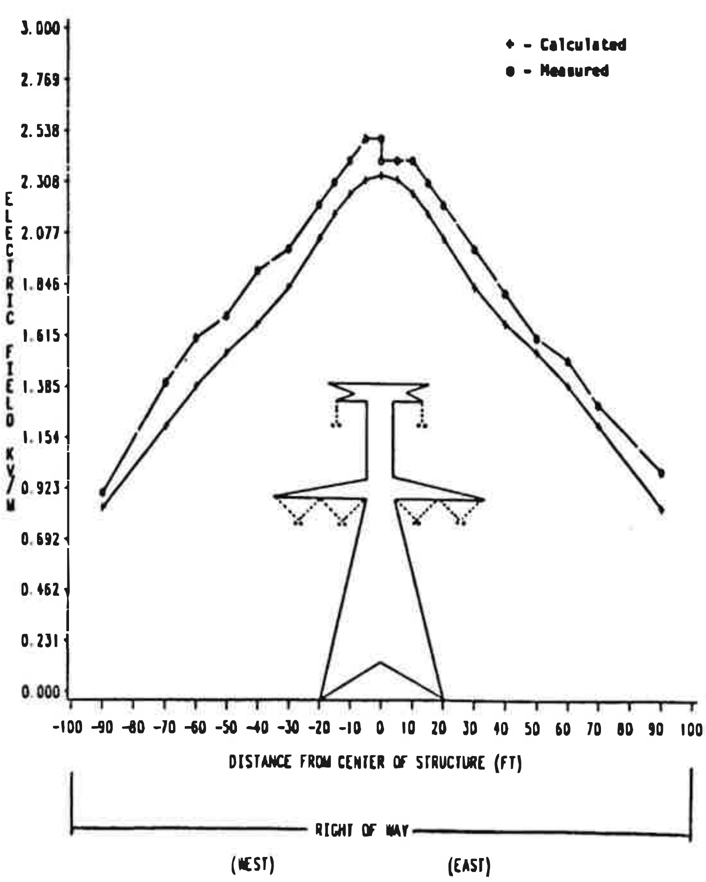

Figure 1. Electric field measurements, 345-kV lattice tower. Conductor height, 63 feet.

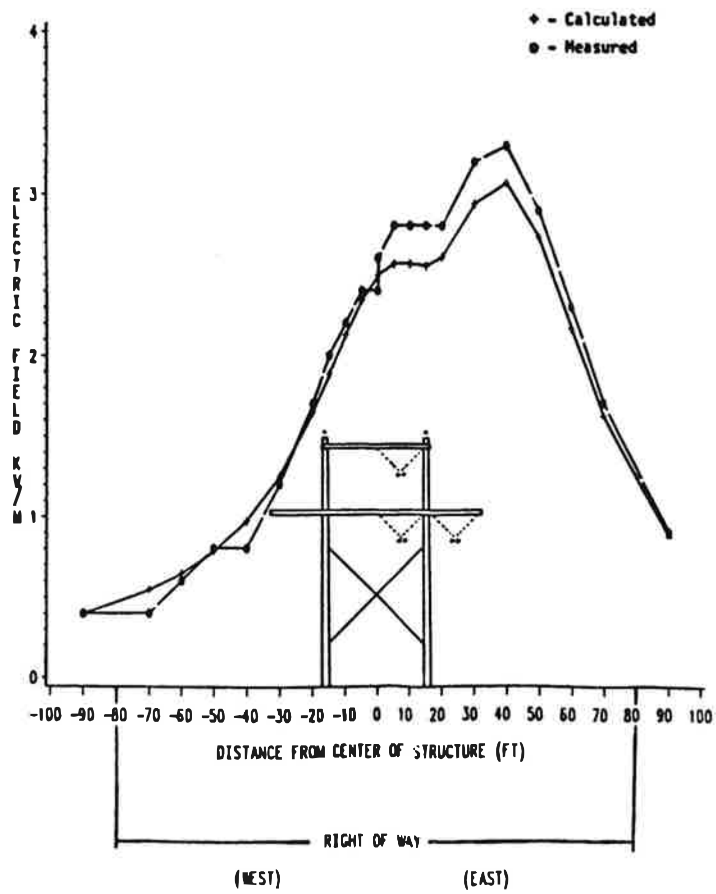

Figure 2. Electric field measurements, 345-kV tubular H-frame. Conductor height, 41 feet.

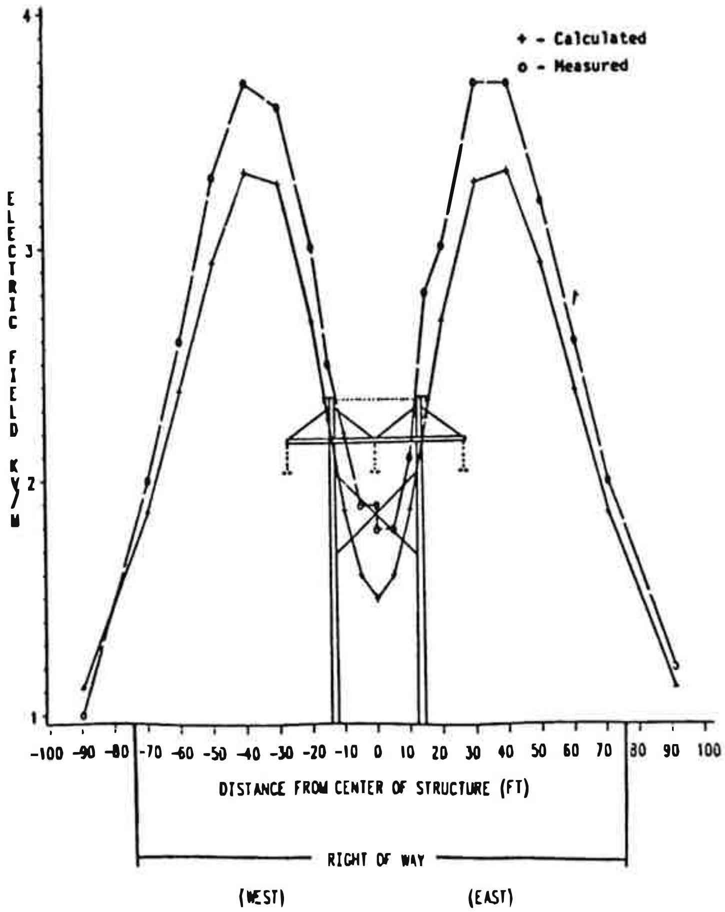

Figure 3. Electric field measurements, 345-kV wooden H-frame. Conductor height, 44 feet.

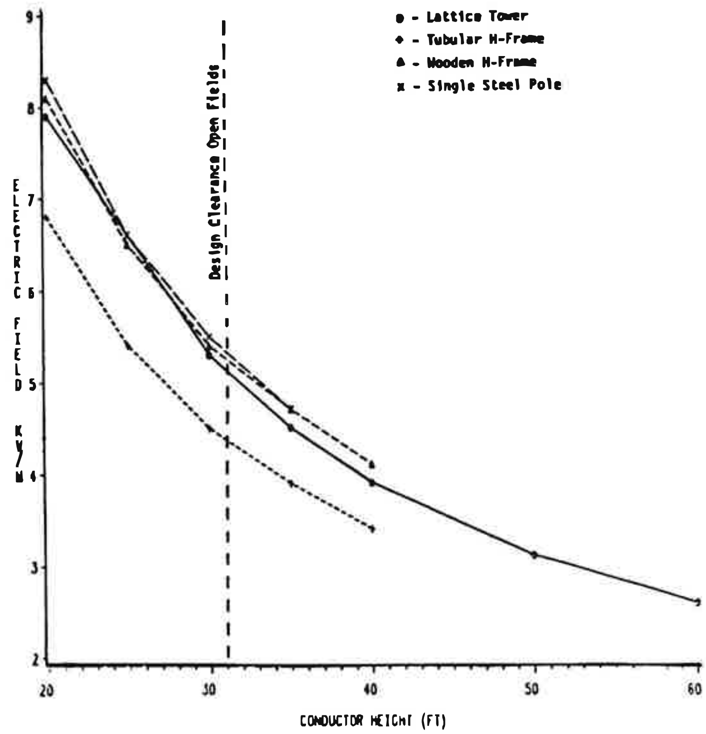

Figure 5. Maximal electric field on ROW.

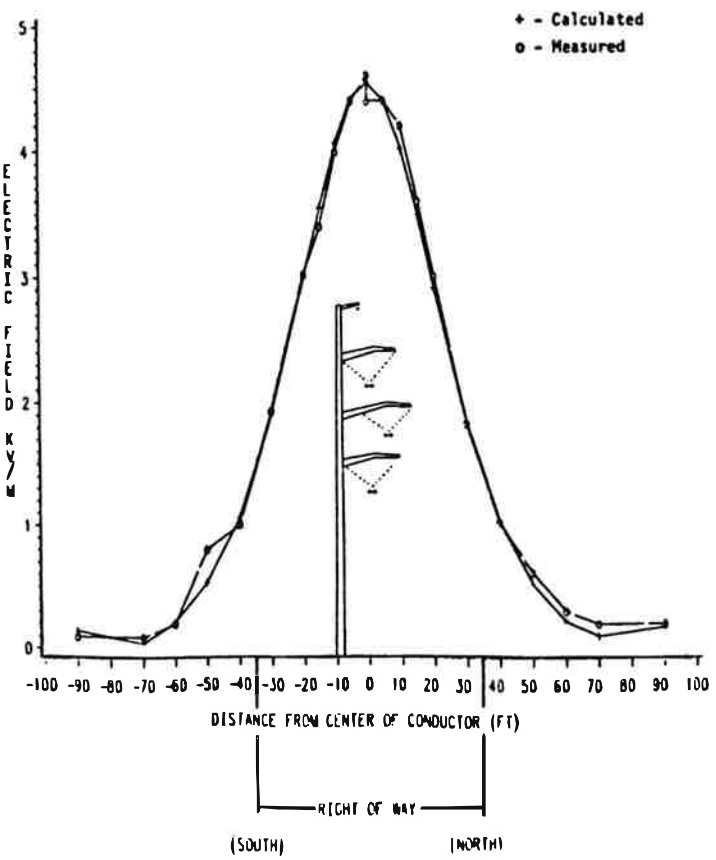

Figure 4. Electric field measurements, 345-kV single steel pole. Conductor height, 36 feet.

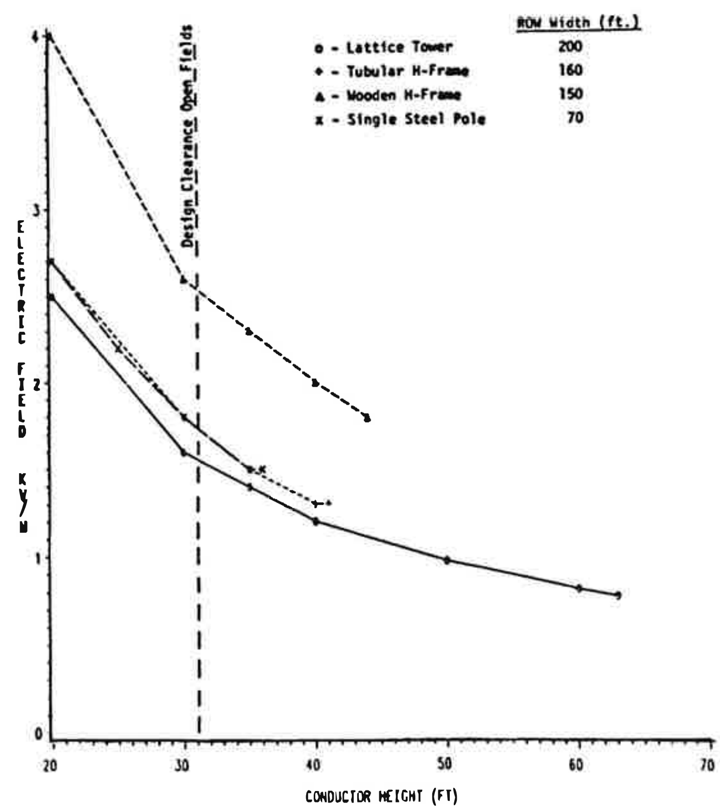

Figure 6. Maximal electric field at ROW edge.

Table 5. Electric Field Strength vs. Phase Conductor Height

Height (feet)	Estimated Field (kV/m)	
	Masimum	ROW Edge
Lattice tower		
20	6.9	2.5
25		
30	5.3	1.6
35	4.5	1.4
40	3.9	1.2
45		
50	3.1	0.98
55		
60	2.6	0.82
63	2.5	0.78
Tubular H-frame		
20	6.8	2.7
25	5.4	
30	4.5	1.8
35	3.9	1.5
40	3.4	1.3
41	3.3	1.3
Wooden H-frame		
20	8.1	4.0
25	6.5	
30	5.4	2.6
35	4.7	2.3
40	4.1	2.0
44	3.7	1.8
Single steel pole		
20	8.3	2.7
25	6.6	2.2
30	5.5	1.8
35	4.7	1.5
36	4.6	1.5

Table 6. Electric Field (kV/m) at 31 Feet

Structure Type	On Row	At ROW Edge
Lattice tower	5.1	1.6
Tubular H-frame	4.3	1.7
Wooden H-frame	5.3	2.5
Single steel pole	5.3	1.7

maximal electric field occurs for the single steel pole at a value of 5.3 kV/m (Figure 5). The National Electrical Safety Code limit of 5 mA induced current is predicted to occur for the largest truck in an electric field strength of 6.25 kV/m. The 50% annoyance threshold for spark discharge from a person occurs at an electric field strength of about 7 kV/m. Comparison of these field strengths with the field strengths in Figure 5 demonstrates that the current OPPD design practices are doing an effective job in maintaining electrical field strengths to acceptable levels.

The above discussion serves to demonstrate how the electric field strength data can be used to compare current OPPD transmission line design with industry practice. A more complete discussion of this subject is found in the report by Graves.[2]

Conclusions and Recommendations

OPPD currently bases its transmission line guidelines on the National Electrical Safety Code. The Florida study reaffirms this practice but also recommends that the state of Florida may wish to develop transmission line electrical effects guidelines or standards that should describe acceptable methods of calculation and standardized transmission line conditions. OPPD, as well as other utilities, may want to consider adopting some or all of the transmission line electrical effects guidelines or standards as recommended to the state of Florida.

References

1. *Description of Equations and Computer Program for Predicting Audible Noise, Radio Interference, Television Interference, and Ozone from A-C Transmission Lines, Bonneville Power Administration Technical Report ERJ-77-167, May 1980.*
2. *Graves, H. B. et al. Biological Effects of 60-Hz Power Transmission Lines. Report prepared for the Florida Electric Power Coordinating Group, Inc., Tampa, Florida, March 1985.*
3. *Lee, J. M., Brunke, J. H., Lee, G. E., Reiner, G. L., and Shon, F. L. Electrical and Biological Effects of Transmission Lines: A Review. Bonneville Power Administration, U.S. Department of Energy, Portland, Oregon, 1982.*