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Lightning Strike Ground Voltage

Dr. Kim D. Coder, Professor of Tree Biology & Health Care / University Hill Fellow
University of Georgia Warnell School of Forestry & Natural Resources

When lightning strikes a tree, the grounding (earthing) volume beneath the tree canopy within soil is proportional to the energy of a strike. Current surges during a lightning strike to soil volume around a tree base can be large for a relatively long distance away from a tree. Figure 1. This energy surge has human and animal health, first aid, and tree root consequences.

The most common injury to humans and animals near a lightning strike (but not directly part of the strike channel) is an induced current through the legs because of voltage differences between ground contacts (feet). Figure 2 demonstrates voltage changes away from a lightning struck tree and its potential to flow through connected ground contact points (i.e. step voltage).

High Stepping

To calculate voltage at the ground surface moving away from a tree lightning strike, the following formula can be used: (from Bazelyan & Raizer, 2000)

Voltage Change Along the Ground Away from a Tree Lightning Strike =

$$[(\text{kA} \times \text{soil resistance in ohms}) / (6.283)] \times [(1 / D) - (1 / (D + \text{Separation})]^2$$

kA	= current of lightning strike (kiloamps)
D	= radial distance from the struck tree to the closest ground contact (feet)
Separation	= radial distance separating ground contacts (feet)

Given the great variability of a lightning strike grounding beneath a tree, no calculated value can accurately represent any strike. Using the formula above, tree health care providers can better understand lightning energy changes at ground level.

Induced Voltage

Figure 3 shows the voltage passing between two ground contacts separated by one foot (30,000amp lightning strike and 25ohm soil resistance). For example, the voltage across ground contacts one foot apart at the soil surface, 50 feet from a tree lightning strike, would be approximately 2,000 volts. At 500 feet from a tree lightning strike, voltage across ground contacts one foot apart at the soil surface would be 240 volts.

A person standing with one side toward a tree lightning strike, and with feet one foot apart, would feel an induced current flow through their legs of 240 volts if they were 500 feet away from the lightning strike. This voltage through leg muscles would cause collapse.

2 Or 4 Legs?

Figure 4 provides approximate voltage passing between two ground contacts radially alined with a tree lightning strike and separated by various distances (in feet), at some distance (in feet) away from the tree base. For example, at 5 feet away from a tree lightning strike (30,000amps and 25ohms), ground contacts 3 feet apart would have a voltage difference between them of 22,000 volts. Large amounts of energy are dissipated close to the tree base. An animal or human sheltering beneath a tree would be seriously impacted.

Figure 5 gives the estimated voltage passing between two ground contacts at some distance (in feet) along a radial line from a tree lightning strike (30,000 amps) and separated by one foot (1 ft.) for different soil resistance values (in ohms). Soil resistance values vary with physical, biological, and chemical features of soil including organic matter content, soil texture, and water content. The greater soil resistance, the farther from a tree large ground voltages can be measured.

For example, 10 feet away from a tree lightning strike with soil resistance of 200ohm, ground contacts would have a 87,000 volt difference, while with a 25ohm soil resistance the difference would be 10,000 volts.

Tree Impacts

Voltage moving through soil as the energy of a lightning strike is dissipated can be great, especially close to the tree and where soil resistance values are large. Tree interactions with dissipation of this energy occur due to root grafting, fine absorbing root distribution, and root contact points with other materials in soil. Tree roots can be badly damaged close to a strike.

Citation:

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Step Voltage

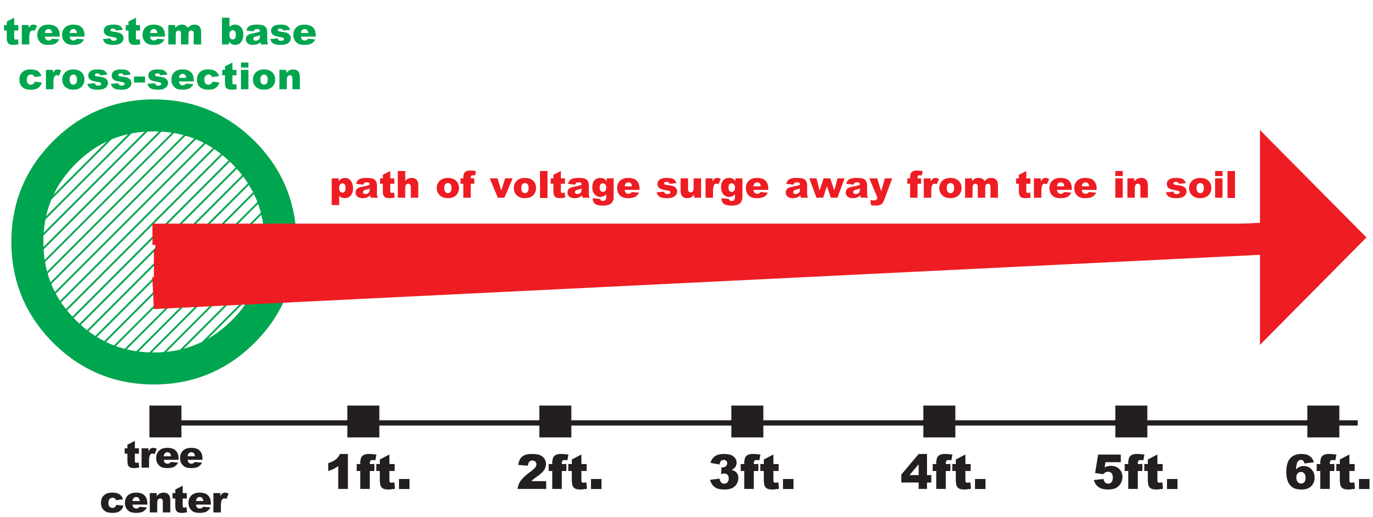
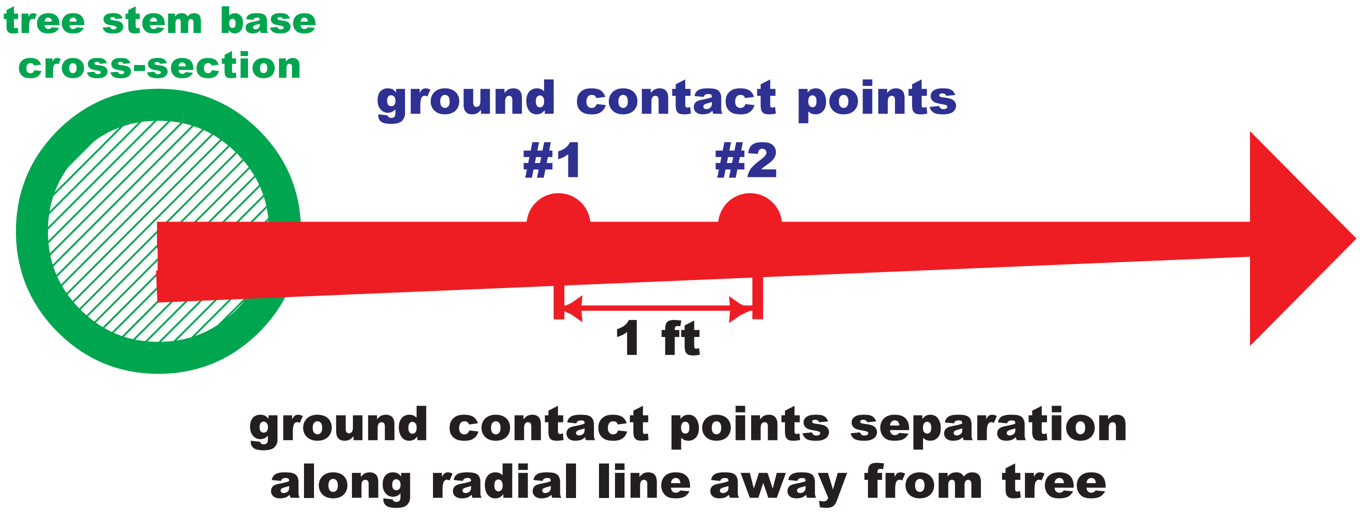


Figure 1: Voltage dissipation in soil away from a tree lightning strike. The perspective is from directly above the tree struck by lightning and its soil surface area along one radial line. The farther from the strike, the smaller the voltage. (Not associated with surface arcing.)



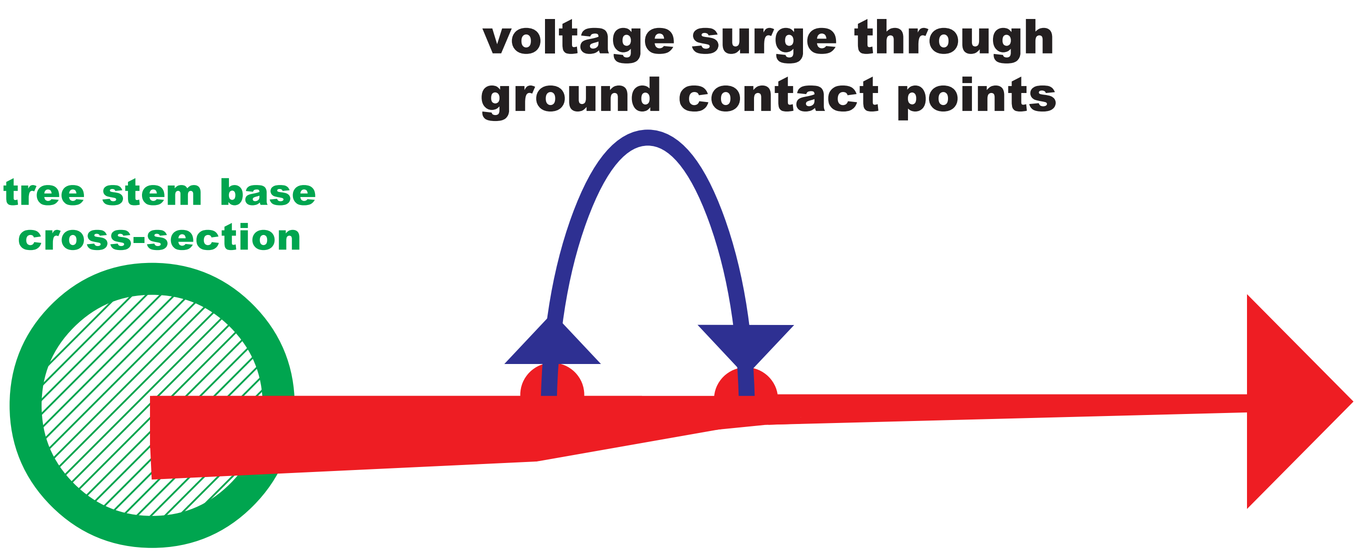


Figure 2: Voltage dissipation in soil away from a tree lightning strike. The farther from a strike, the smaller the voltage. Two ground contact points which are interconnected above ground may have current flowing through them due to the voltage differences between each ground contact point. (Not associated with surface arcing.)

closest radial distance from tree (feet)	approximate voltage across ground contacts separated by 1 ft. radially (volts)
1 ft.	89,000 volts
2	46,000
3	32,000
4	25,000
5	20,000
6	17,000
7	15,000
8	13,000
9	12,000
10	10,000
20	5,000
30	3,000
40	2,000
50	2,000
60	1,000

closest radial distance from tree (feet)	approximate voltage across ground contacts separated by 1 ft. radially (volts)
70	1,000
80	1,000
90	1,000
100	1,000
150	800
200	500
250	475
300	395
400	300
500	240
600	200
700	170
800	150
900	132
1,000	120

Figure 3: Estimated voltage (step voltage) passing between two ground contacts separated along a radial line by one foot (1 ft.) at some distance (in feet) from a tree struck by lightning (30,000amps lightning strike & 25ohm soil resistance).

closest radial distance from tree stem (feet)	radial distance of separation between ground contacts			
	0.5 ft.	1.0 ft.	3.0 ft.	5.0 ft.
1 ft	66 kV	89	111	116
2	40	46	54	57
3	30	32	36	37
4	23	25	27	28
5	19	20	22	22
6	17	17	18	18
7	14	15	15	16
8	13	13	13	14
9	11	12	12	12
10	10	10	11	11

Figure 4: Estimated voltage (step voltage) passing between two ground contacts separated along a radial line by various distances (in feet) at some distance (in feet) from a tree stem struck by lightning. (30,000amp lightning strike & 25ohm soil resistance).

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closest radial distance from tree stem (feet)	soil electrical resistance measures (ohms)							
	25	50	100	150	200	250	300	400
1 ft.	89kV	179	358	537	716	895	1074	1432
2	46	92	185	278	371	464	557	742
3	32	64	129	193	258	323	387	517
4	25	50	100	150	200	250	300	401
5	20	41	82	123	164	205	246	328
6	17	34	69	104	139	174	209	279
7	15	30	60	91	121	151	182	242
8	13	26	53	80	107	134	161	215
9	12	24	48	72	96	120	144	193
10	10	21	43	65	87	109	131	175
20	5	11	22	34	45	56	68	91
30	3	7	15	23	30	38	46	61
40	2	5	11	17	23	29	34	46
50	2	4	9	14	18	23	28	37

Figure 5: Estimated voltage (step voltage in kilovolts (kV)) passing between two ground contacts at some distance (in feet) along a radial line from a tree lightning strike (30,000amps) and separated by one foot (1 ft.) across various soil resistance measures (ohms).