Mechanisms of Vegetation-Caused Faults on Electric Power Lines

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Carl L. Benner and Dr. B. Don Russell

Vegetation intrusion causes problems with electric power lines through a variety of mechanisms. Outage reporting systems typically include “vegetation” as a broad cause category for tracking outage statistics, but improved understanding of vegetation-related issues requires tracking of the precise root causes of vegetation events. This white paper overviews multiple vegetation-related mechanisms common to overhead power lines. It does not purport to examine every possible scenario.

Vegetation can interfere with secondary service conductors (i.e., less than 1 kV), primary distribution conductors (i.e., 1 kV through 35 kV), or transmission and sub-transmission conductors (i.e., above 35 kV). This white paper focuses on vegetation interfering with primary distribution conductors.

Mechanisms by which vegetation causes power line faults fall into broad categories of electrical and mechanical. Mechanical mechanisms include wind or ice loading causing tree branches to push conductors together. Mechanical mechanisms also include trees falling into power lines and breaking conductors. In such cases, the broken conductor(s) may contact other intact or broken conductor(s) or earth. Although vegetation precipitates all of these events, the resulting contacts are mechanical in nature and differ little from those resulting from non-vegetation factors that move or break conductors (e.g., an automobile striking a pole).

Electrical fault mechanisms include events such as branches spanning the separation between two phase conductors or between a phase conductor and a neutral. Electrical mechanisms also include vegetation spanning the separation between an energized conductor and the earth, typically consisting of a tree leaning into a phase conductor while maintaining contact with earth.

Texas A&M Engineering has conducted experimental investigations into electrical mechanisms associated with vegetation contacting conductors of a 12.5/7.2 kV, multi-grounded-wye primary distribution circuit. Each experiment involved a branch in continuous, simultaneous contact with a phase conductor and a neutral conductor, with three to four feet of separation. These experiments led to the conclusion that such contact typically does not immediately produce high-amplitude fault current. Rather the contact initially produces minimal current (less than one ampere). During that early period, arcing, flame, steam, and smoke appear along the portion of the branch that lies between the conductors, progressively charring the surface of the branch. Hissing and squealing sounds may occur as moisture in the branch flashes to steam and vents through branch bark. The visible and audible activity during this period give an impression of substantial current flow, but electrical measurements indicate that current generally remains in the one-ampere range. If the branch maintains good contact with both conductors for several minutes, without the branch burning in two and falling clear or otherwise losing contact with one or both conductors, the current may increase to an ampere or so, over a period of perhaps minutes, and

then transition suddenly to a high-current flashover. The prolonged, low-amplitude flow of current can damage the conductor, at the points of contact, as can any high-amplitude flashover events that may occur. The aforementioned process occurs when the branch contains moisture. Almost no measurable current flows when the branch is dead and well dried [1,2].

Texas A&M Engineering also conducted experiments that involved placing a phase conductor, of the same multi-grounded-wye, 12.5/7.2kV power line, into contact with a large branch of a live tree, at a height consistent with conventional overhead distribution construction. Fault current flowing down the tree and to the earth did not exceed a few amperes, even when intimate contact between the phase conductor and the tree was maintained continuously for multiple minutes, but the prolonged, low-amplitude flow of current damaged the conductor at the point of contact.

Goodfellow and Appelt also conducted experimental investigations into electrical mechanisms related to vegetation faults. A general conclusion of their work, consistent with the Texas A&M work, indicated that development of significant fault current requires a minimum voltage gradient of approximately 2 kV per foot along a branch spanning the normal separation between conductors [3].

Tip pruning is something of a special case. Tender new growth at the tips of branches has high moisture content and often experiences tip pruning, as those new tips come into casual contact with overhead distribution conductors. Relatively small flow of current is sufficient to prune the tips and temporarily remove the contact. In this case, higher-current faults are unlikely.

Electrical mechanisms associated with vegetation contacting power lines are complex and affected by numerous factors. Factors include vegetation species, vegetation moisture, environmental moisture, and branch size. Each factor affects current flow and the possible progression to full flashover.

Research supports the general conclusion that a live tree branch intermittently contacting a single 7.2 kV phase conductor likely will not create a high-current fault or cause substantial conductor damage [4].

<u>Distribution Fault Anticipation (DFA) Technology and Vegetation Faults</u>

DFA Technology detects higher-amplitude faults related to vegetation-caused mechanical teardown or contact between conductors and assists in the location of such events. DFA detects repetitive faults related to vegetation contacts and provides assistance in locating the underlying problem.

[1] K. L. Butler, B. D. Russell, C. Benner, K. Andoh, "Characterization of Electrical Incipient Fault Signature Resulting from Tree Contact with Electric Distribution Feeders," Proceedings of the 1999 IEEE Power Engineering Society Summer Meeting, 99CH36364, July 1999, pp. 408-413.

[2] J. A. Wischkaemper, C. L. Benner, B. D. Russell, "Electrical Characterization of Vegetation Contacts with Distribution Conductors – Investigation of Progressive Fault Behavior," Proceedings of the 2008 IEEE Transmission and Distribution Conference and Exposition, Chicago, Illinois, April 21-24, 2008.

[3] Paul J. Appelt and John W. Goodfellow, "Research on How Trees Cause Interruptions – Applications to Vegetation Management," Proceedings of the 2004 IEEE Rural Electric Power Conference.

[4] "Best Practices in Vegetation Management for Enhancing Electric Service in Texas," Public Utility Commission of Texas project 38257, September 2011.