Managing Tree-caused Electric Service Interruptions

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Throughout their one hundred year history, utilities have been challenged by tree-conductor conflicts. On transmission systems tree-conductor contacts can have devastating results as demonstrated by the fact that trees were involved in the last three major cascading outage events in North America. For many utilities, trees are the number one cause of unplanned distribution outages. Across the utility industry, tree-related outages commonly comprise 20% to 50% of all unplanned distribution outages. While these percentages indicate trees are a major threat to reliability, the convention of excluding outage statistics arising from severe storm events means the extent of the problem is, in fact, understated.

Considering the long history of attention and resources focused on reducing or eliminating tree-conductor conflicts, the incidence of tree-caused cascading outages originating on transmission systems, the general extent of the ongoing level of tree-related outages on distribution systems, and the regularity of extensive tree-caused storm damage suggests something is missing. What is missing must be an understanding of what outages can be avoided, through what actions and where we can reasonably expect a reliability benefit for the dedication of additional resources.

Drawing on industry data, tree-caused outages will be categorized to identify opportunities for electric system improvement. In the process of doing so we will answer the following questions, questions that will guide us in formulating what constitutes realistic expectations.

1) Can the 'best in class' of typical utility vegetation management (UVM) programs meet the reliability expectations of customers and regulators – during normal operating conditions and during major storm events?
2) If not, can a more rigorous hazard tree program substantially reduce tree-related outages?
3) What is the contribution of apparently healthy tree failures on outage incidents – during normal operating conditions and during major storm events?

What Trees Give Rise To Service Interruptions

Most tree-related outages are due to tree failures and these trees are outside the right of way.[1] Rees, of Baltimore Gas & Electric, attributed only 2% of all tree-related outages to trees growing up into a line.[2] Guggenmoos showed tree growth to account for 2% to 10% of tree-related outages on TransAlta Utilities' distribution system.[3] Finch, reporting on Niagara Mohawk's tree-caused outages, indicates tree growth accounts for 14% of outages,[4] while Rogers explains part of the reasoning behind Puget Sound Energy's Tree Watch program is that only 13.5% of tree-related outages are attributable to tree growth.[5] Since 1997 Puget Sound Energy's tree pruning program has become more effective as less than 5% of tree-related outages are attributable to in-

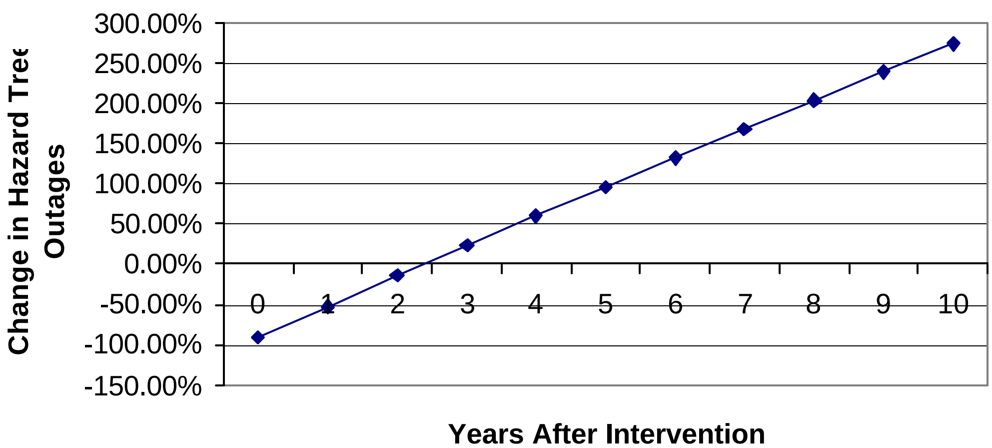
1 Guggenmoos, S. Effects of Tree Mortality on Power Line Security. Journal of Arboriculture, 29(4), July 2003.
2 Rees, Jr. William T., Timothy C. Birx, Daniel L. Neal, Cory J. Summerson, Frank L. Tiburzi, Jr., and James A. Thurber, P.E. 1994. Priority Trimming to Improve Reliability. ISA Conference presentation, Halifax, Nova Scotia, 1994.
3 Guggenmoos, S. 1996. Outage Statistics - As a Basis for Determining Line Clearance Program Status. UAA Quarterly, 5(1), Fall 1996.
4 Finch, K.E., C. Allen 2001. Understanding Tree Caused Outages. EEI Natural Resource Conference, Palm Springs, CA, Apr. 2001.
5 Rogers, Beth, I. 2001. Puget Sound Energy Tree Watch Program. EEI Natural Resource Conference, Palm Springs, CA, Apr. 2001.

growth.[6] From these geographically, ecologically diverse utility systems a common thread emerges: tree growth into power lines accounts for less than 15% of all tree-related outages.

If in-growth causes only 2 to 15% of tree-caused interruptions, then 85-98% must be attributable to tree in-fall. Storm loading, whether wind or ice, results in tree failures - either branch or trunk breakage or uprooting. Simply by the fact that the number of trees outside the right of way, which can affect continuity of service, vastly outnumbers such trees within the right of way, most of the 85% or more of in-fall outages arise from trees located outside the right of way. On distribution systems, the maintained right of way typically represents only 10-20% of the utility forest land base.[7] For transmissions lines (69 kV and above), where the tolerance for trees within the right of way is considerably lower, the maintained right of way generally represents 30-70% of the utility forest.[8]

Utilities seek to prevent outages due to tree failure through hazard tree removal programs. However, due to re-stocking and natural tree mortality, the hazard tree removal program provides a reliability benefit of limited duration. Assuming average distribution line construction and line clearance standards, a 1% annual tree mortality rate, and what would be considered an aggressive hazard tree program that removes an average of ten trees per mile of line the reliability benefit endures for only 2 years (Figure 1).

Figure 1: Hazard Tree Removal Benefit Duration



Source: Optimal Clear Width Calculator

Mortality of trees is a process, which occurs over a period of time. As it would be unlikely for all but the very smallest utilities to remove all hazard trees within days or a few weeks, there is an ongoing residual population of hazard trees. Indeed, most utility hazard tree programs cover their service territory but once over a period of three to eight years. It is, therefore, unreasonable to expect no outages to arise from hazards trees. A utility simply cannot monitor all the trees in the

6 Guggenmoos, S. 2009. Storm Hardening the Electric Transmission System. Report produced for Puget Sound Energy, March, 2009.
7 Guggenmoos, S. Effects of Tree Mortality on Power Line Security. Journal of Arboriculture, 29(4), July 2003.
8 Guggenmoos, S. Effects of Tree Mortality on Power Line Security. Journal of Arboriculture, 29(4), July 2003.

utility forest all at once. There should, however, be a relationship between the number of trees removed annually by the hazard tree program and the number of trees added annually to the hazard tree population through natural tree mortality. If no such match exists, there will be an increasing population of hazard trees. As the hazard tree program falls further behind, these trees will become increasingly more vulnerable to failure under decreasing levels of stress load.

The identification of hazard trees is challenging. Death of a tree commonly occurs over a period of years. Invasive and destructive methods of tree evaluation are not an option. Utility personnel must rely on exterior symptoms of decadence, which may take years to appear. Bearing in mind the fact of an unavoidable residual hazard tree population, utilities do reasonably well in identifying hazard trees, as less than one half of the failed trees causing outages are hazard trees. Indeed, the majority of trees that fail have no visible fault indicator. Both Eastern Utilities Associates[9] and Puget Sound Energy[10] found 56% of failed trees had no visible indication of fault. Another 12% of trees, which cause outages on Puget Sound Energy's system, are in fair health and therefore, difficult to justify as removals.

That more than 55% and up to 70% of the trees causing outages have no discernable defect has important implications for understanding and mitigating tree-related outages. It suggests that successful mitigation will necessitate a reduction in the electric system tree exposure. This implication has been verified by work on the National Grid[11] and Puget Sound Energy[12] transmission systems. It was found line height, tree height and clear width, variables that impact the arc of power line exposure, are not significantly correlated to tree-caused outage frequency. However, trees per mile edge, a measure of tree exposure, is significantly correlated to tree-caused outage frequency, with r values (coefficient of correlation) of 0.85 and 0.92, respectively. The strong correlation informs us that the sure way of reducing tree-caused outages is to reduce the electric system's extent of tree exposure. As a result, it is unreasonable to expect conventional utility vegetation management programs to drastically reduce tree-related service interruptions. Such programs do not target the apparently healthy trees, which account for 55-70% of tree-caused interruptions. If the average percent of healthy trees contributing to outages is 56%, then one would expect during major storm events that the percentage of healthy tree failures is even greater, dependent upon both the degree of stress loading and duration, the decadent trees being removed from the utility forest in minor storms or early in the major storm event. A recent study of Puget Sound Energy's transmission system provides support for this assertion.

Using ten years of outage and wind data to determine tree failure rates, it is found that tree failures occur exponentially to wind speed (Figure 2).[13] Tree failures increase rapidly at wind speeds over 60 mph. If we assume all hazard trees fail and are removed from the utility forest population at or below 60 mph winds, then a storm of 75 mph winds would have tree failures

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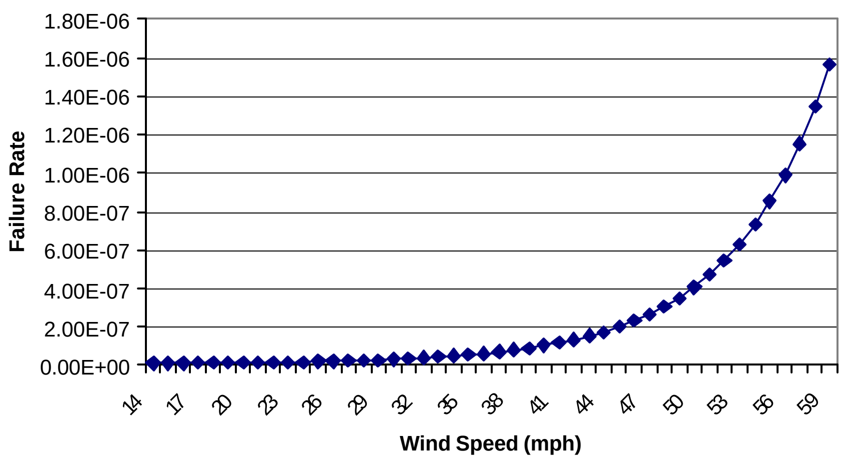
9 P. Simpson, R. Van Bossuyt. "Tree-Caused Electric Outages," *Journal of Arboriculture* 22(3): p.117, May 1996.
10 Guggenmoos, S. 2009. Storm Hardening the Electric Transmission System. Report produced for Puget Sound Energy, March, 2009.
11 Guggenmoos, S., T.E. Sullivan. 2007. *Outside Right-of-Way Tree Risk Along Electrical Transmission Lines*. Utility Arborist Association Mar. 2007. http://www.utilityarborist.org/images/Articles/SideTreeRisk.pdf
12 Guggenmoos, S. 2009. Storm Hardening the Electric Transmission System. Report produced for Puget Sound Energy, March, 2009.
13 Guggenmoos, S. 2009. Storm Hardening the Electric Transmission System. Produced from data of Puget Sound Energy, March, 2009.

comprised of only 4% hazard trees and 96% healthy trees (Figure 3). That is, 96% of the outages can be considered to be unpreventable. This leads to two conclusions: that there is only one means of avoiding tree-related outages during major storms - reducing electric system tree exposure; and even if all hazard tree outages could be avoided, the elimination of those outages does not significantly reduce storm damage.

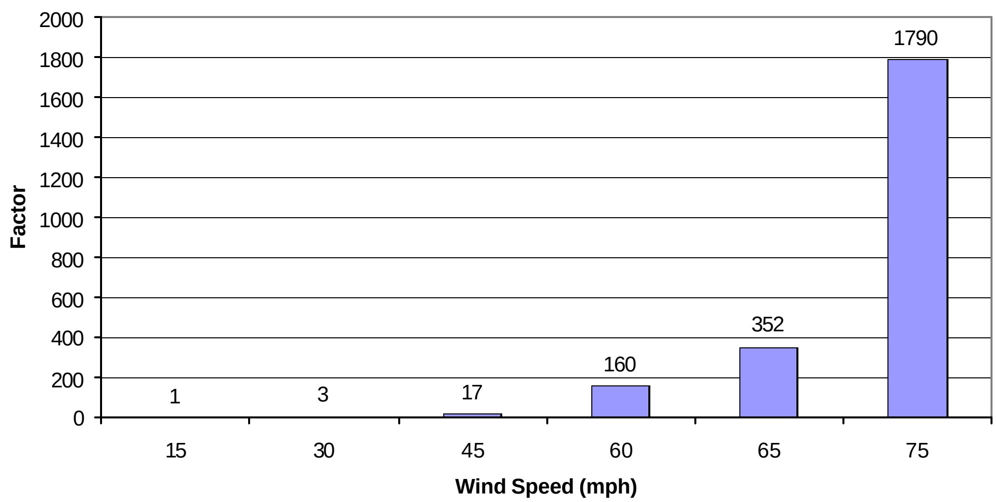
Increasing the intensity of the hazard tree program will not noticeably improve electric system performance during major storm events.

Figure 2: Tree Failure Rate



Source: Puget Sound Energy, Storm Hardening the Electric Transmission System

Figure 3: Tree Failure Ratio



Source: Derivation of Puget Sound Energy, Storm Hardening the Electric Transmission System data

Managing (Perceptions of) Electric System Performance

The implication of the exponential increase in outages in response to increasing wind speed is that the success or lack of a hazard tree program has little bearing on the number of outages experienced during a major wind storm event. One might surmise the same would apply to major ice storms with decadent branches failing with modest ice loads and a far greater number of healthy branches failing when ice coating exceeds ½ inch. This does not make the hazard tree program irrelevant. It is simply that the benefit of the hazard tree program is realized at winds of less than 60 mph, that is, during what tends to be frequent, minor storms.

Considering 15-30% of tree-caused interruptions are typically due to hazard trees, there is the possibility of material contributions to reliability. However, hazard tree programs have many challenges that can impact their efficacy.

- Very few utilities know the average number of hazard trees that are annually added to their system. You can't manage what you don't measure.
- The duration of benefit of the hazard tree program is generally believed to be greater than it actually is. Some even believe the benefit is permanent; a false notion dispelled by focusing on the forest rather than the individual tree.
- Most hazard trees are located on private property; perceived not as a liability but an asset by the landowner.
- There is no cost effective, practical means of patrolling for hazard trees that are 30 feet or more inside the forest edge.
- There being no means of instantaneously assessing or monitoring tree health on a system wide basis, utilities are left to make judgments about appropriate inspection and maintenance cycles, balancing costs and line security.
- Environmental conditions such as drought or pest infestations can dramatically impact the tree mortality rate.

Utilities can eliminate a number of these challenges by determining their total tree exposure and natural tree mortality rate, which permit the calculation of the number of annual hazard tree additions and the funding requirements to address them, therein providing unarguable justification for funding the hazard tree program. However, as previously stated, the benefits of even the best possible hazard tree program will be realized predominantly during normal operating conditions not during major storms events.

One question remains to be answered. Can the 'best in class' of typical UVM programs meet the reliability expectations of customers and regulators – during normal operating conditions and during major storm events?

The 'best in class' <u>typical</u> UVM does not generate complaints about reliability during normal operating conditions. However, such programs often receive heavy criticism for system performance during major storms. Work on National Grid and Puget Sound Energy systems found only decreasing tree exposure could avert outages during major storms. This is probably true for electric systems in general. Measures to decrease tree exposure involve actions that are resisted by landowners (i.e. widening right of ways) or generally considered too expensive by the regulators and public (i.e. undergrounding).

It is common that a public displeased with the extent of storm damage and restoration time will not support the actions that can change the outcome in future storm events. There is a way off the horns of this dilemma. Do not let the public define expected system performance. Rather, utilities should provide regulators, and thereby the public, with performance expectations for their system under normal and storm operating conditions. In this way public perception can be controlled, requiring only that the utility system meet the articulated level of performance. Failing to create the performance expectation leaves utilities to satisfy the unarticulated, uninformed reliability expectations of the public.