

# TREE-CAUSED ELECTRIC OUTAGES

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**Abstract.** In 1995, Eastern Utilities was among 14 utilities in the United States and Canada participating in a study to collect and evaluate data about the phenomena of how trees cause outages. Results indicate that failure of trees accounted for 40% of the *preventable* tree-caused outages in the Brockton territory of Eastern Utilities. Even though line clearance tree trimming continues to be the primary strategy, *programmatically changes were made in Eastern Utilities' Tree Management Program.* A Danger Tree Project was initiated to identify and mitigate trees with structural weaknesses along the 3-phase portion of the electrical distribution circuits. Approximately 4% of the trees in the portion of the urban forest managed by Eastern Utilities will either be removed or storm-proof pruned. Reliability has improved by 20% to 30% along the circuits where hazardous trees have been removed or storm-proof pruning has been done. Proactive communication within the community and participation in community-based tree planting has accompanied this project.

Electric utilities trim trees to minimize tree-caused electrical outages. (Outages are the interruption of electrical service to customers.) Typically, the expense to trim trees is a significant percentage of the maintenance budget of an electric utility. In spite of this expenditure, trees continue to be the greatest single cause of outages for many electric utilities. To minimize tree-caused outages, maintaining clearance between tree growth and energized conductors is the strategy for most utility tree management programs. Yet the phenomenon of tree-caused outages has not been empirically researched.

In 1995, 14 utilities in the United States and Canada subscribed to the Tree-Caused Interruption Research Project conducted by Environmental Consultants, Inc. (ECI). The outage study consisted of a survey to collect and analyze data about individual tree-related outage events. The goal of the study was to develop regional and overall databases to identify and analyze the factors involved with tree-related outages.

Eastern Utilities was a participant in the study. Results of the study led to programmatic adjust-

ments in Eastern Utilities' approach to tree management, consisting of a modification of practices for line clearance tree trimming and initiating a Danger Tree Mitigation Project. These changes were based on the study's cumulative analysis for all participants, a study analysis specific to Eastern Utilities, a survey of the tree population adjacent to primary electrical circuits in one of Eastern Utilities' service territories, and a review of the outage history from trees at Eastern Utilities for the years 1989 to 1994.

## Methods

The study was designed to collect data on 22 factors that describe the conditions of a tree-related electrical outage. A standardized data collection form was designed by ECI with input from the participants of the study. Data compilation and analysis was done by the ECI staff.

Eastern Utilities also conducted a survey of the urban forest adjacent to the primary electrical circuits of the distribution network in its Brockton service territory and reviewed the outage history from 1989 to 1994. The primary electrical circuits consist of pole spans with single and multiple electrical conductors, called phases. The survey was designed to locate trees on the 3-phase portions of these circuits with the characteristics that are most likely to cause an outage. Also, an outage history of the primary circuits was reviewed to identify areas that have been historically prone to tree-caused outages.

**Data collected for outage study.** The study was organized to collect data on tree-caused outages by the following 6 categories:

1. cause of the outage
2. characteristics of the tree
3. surrounding environment
4. orientation of tree to electrical conductor

5. weather conditions at the time that the outage occurred
6. components and design of the electrical system at the site of the outage.

In addition, the arborist assessed whether the outage was preventable or nonpreventable. This assessment was based on whether the tree would still have caused the outage after the normal cycle of line clearance trimming was done. For instance, if a tree with adequate clearance and no apparent indicators of structural weakness fails during a sunny winter day with 25 mile per hour winds, it was considered nonpreventable.

The categories describing the cause of the outage were broken down into growth or failure. The 3 growth-related indicators are top growth, side growth, or bending limb. Tree failures were matched with a choice of 6 descriptors. The type of contact made between the energized conductor and tree, such as tree to conductor or tree broke conductor, was recorded.

Characteristics of the tree classify typical physical features of the tree such as size and species. The condition of the tree that failed has 14 sub-categories that describe the apparent structural defect (or lack of) that probably resulted in an outage. Also, the last time the tree was trimmed, if ever, and the technique used was logged.

Information about the surrounding environment, orientation of the tree to the electrical conductor, and weather conditions at the time the outage occurred was collected. These factors describe the conditions that likely triggered a tree-caused outage event. The data about wind conditions were categorized using the Beaufort Scale and orientation of the tree to the electrical conductor. The weather was classified by 10 general descriptions.

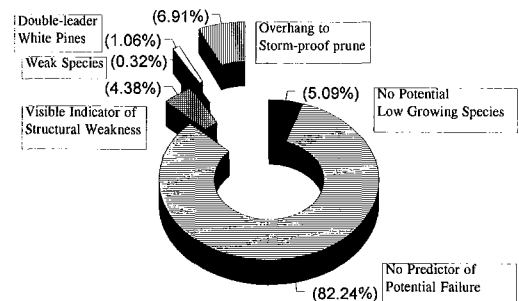
The type of construction and type of conductor at the site of an outage were recorded. Six data were collected that depict the electrical engineering portion of the outage event. The factors are

1. protective device, such as fuses
2. construction type, such as armless, vertical, spacer cable, and crossarm
3. conductor type
4. conductor size

5. line voltage
6. number of phases involved.

**Tree population survey.** A survey of the tree population was conducted in the Brockton territory of the Eastern Utilities system. The territory consists of 17 communities and covers approximately 300 square miles. The objective of the survey was to locate trees with the characteristics that present the greatest risk from failure to the 3-phase portion of the distribution circuits. The survey was a simple random sample of 40% of the number of pole spans for the 3-phase portion of the primary electrical circuits. Random pole spans were selected on a map of primary circuits and the characteristics of the trees within those pole spans were categorized. The trees were categorized along the following 6 indicators of their potential to cause an outage from failure:

1. no predictor of potential failure
2. visible structural defect
3. overhanging limbs
4. weak species
5. white pines with co-dominant stems
6. no potential low growing species.



**Figure 1. Categories of indicators of potential structural failure.**

The percentages of these indicators of the potential for structural failure for the Brockton service territory is depicted in Figure 1.

**Tree-related outage history.** The history of tree-related outages for primary electrical distribution circuits in the Brockton territory was examined for the years 1989 through 1994. The objective of this analysis was to identify the circuits that were most prone to outages from tree or limb failure. The severity of an outage was

based on the quantity of Customer Outage Hours. Customer Outage Hours is the number of customers affected multiplied by the duration in hours of the outage. Outages of the 3-phase portion of electrical distribution circuits usually incur the greatest Customer Outage Hours because they deliver power to large blocks of customers and may be time consuming to restore. This review excluded extended severe weather, such as hurricanes and ice storms; therefore, the data relate to "normal" operating conditions. The normal operating condition distinction can be generalized as sustained winds less than 60 miles per hour and precipitation that does not cause significant damage to trees.

### Results and Discussion

The interim results (January to September 1995) of the outage study for all participants indicate that tree or limb failure accounted for almost two-thirds of all (preventable and nonpreventable) tree-related outages by event frequency. Growth was the most frequent cause of *preventable* outages; however, preventable outages from tree or limb failure was more than 25% of the total.

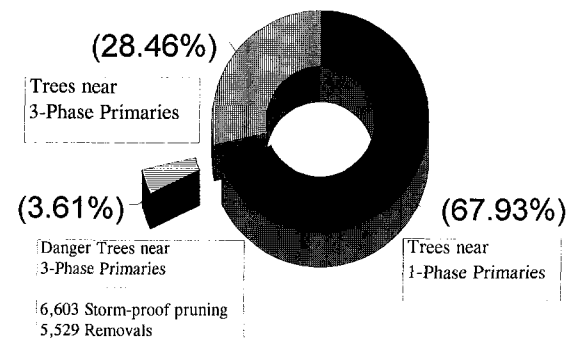
Presently, tree-related outages from growth are not significant in the Brockton territory. This is because Eastern Utilities is now on a 4-year cycle of maintaining clearances between trees and its power lines. This 4-year cycle began in 1990 and was completed in the Brockton territory in 1994. Evidence of the effectiveness of line clearance tree trimming on growth is demonstrated by the fact that trees caused 14% of all outages in 1989, accounting for 27.5% of Customer Outage Hours. Since 1993, however, the number of tree-related outages has hovered around 10% of total outages, accounting for an average of 19% of all Customer Outage Hours.

Structural failure of a limb or tree accounted for 40% of the *preventable* tree-caused outages from January to September 1995. During this period, 73% of the total Customer Outage Hours caused by trees occurred on one of the 5 stormy days. All of these outages were caused by tree or limb failure. Wind speeds during these 5 storms exceeded 45 mph, but were less than 60 mph, so they can be considered normal operating condi-

tions. Most of the Customer Outage Hours occurred on seven of the circuits in a distribution system of over 50 circuits. Review of the outage history for the Brockton service territory revealed that these *same* 7 circuits were involved in at least 40% of the total Customer Outage Hours from trees during the years 1990, 1992, and 1994. Approximately 44% of the trees or limbs that caused an outage during these 5 storms in 1995 had an indicator of structural weakness.

The distribution of the tree population in relation to the electrical network in the Brockton service territory is depicted in Figure 2. In summary, approximately 325,000 trees are trimmed to maintain clearance with electric lines. This excludes the service wires from a pole to a house. Approximately 30% (95,966) of the trees are adjacent to the 3-phase portion of electrical distribution circuits. Only 4% (12,159) of the trees are near the 3-phase portion of the primary circuits and had some indicator of structural weakness or did overhang the energized conductors. These trees with structural weaknesses adjacent to the 3-phase portion of the electrical circuits were those targeted for removal or storm-proof pruning in the Danger Tree Mitigation Project.

**Danger Tree Mitigation Project.** In January 1995, Eastern Utilities launched a Danger Tree Mitigation Project. This project was confined to the 3-phase portion of the primary electrical circuits.



**Figure 2. Distribution of tree population in relation to the portion of primary circuits in the Brockton service territory.**

Determining mitigating circumstances with a high probability of tree failure is based on the risk management principles of

1. identifying assets and exposures—3-phase primary electrical circuits
2. measuring risks—the cost of removing or storm-proof pruning a tree versus the cost of an outage by that tree, including the intangible cost of customer relations
3. controlling risks—removing a hazardous tree, cutting back overhang, and storm-proof pruning.

The goal of the project is to reduce the likelihood and magnitude of damage from winds from 45 to 60 mph along circuits with a history of high tree-caused outages. It is beyond the scope of the Danger Tree Mitigation Project to eliminate all of the outages from tree or branch failure during major storms.

As of October 15, 1995, 3,750 trees had been removed in the Brockton territory. The total number of trees expected to be removed during the initial stage of the project is 5,530. In addition to removing structurally unsound trees, approximately 6,200 trees will either be storm-proof pruned or have overhanging limbs cut back. Storm-proof pruning consists of alleviating a less serious indicator of structural weakness. Most of the storm-proof pruning consisted of thinning the crown or reducing the height of a tree to reduce its "sail" effect.

**Adjustments to line clearance trimming.** The Danger Tree Mitigation Project was undertaken with no additional funding, because of adjustments in the Line Clearance Tree Trimming Program. Most of the tree management expenditures at Eastern Utilities will continue to be concentrated on trimming growth for distance-based clearance. The Line Clearance Tree Trimming Program is on a 4-year cycle. Funding for the Danger Tree Mitigation Project came from adjustments to the methods used in line clearance tree trimming. These adjustments consist of doing less trimming of growth beneath the lines. Doing less trimming to growth from beneath is based on the belief that undergrowth is less likely to cause a phase-to-phase outage on horizontal or delta construction than contact from side growth. Also, only 75% of

sucker growth in the clearance envelope is being removed. The remaining 25% of suckers are being cut in half, based on the premise that their elongation will slow down and they will inhibit some resuckering.

**Communication within the community.** Before launching the Danger Tree Mitigation Project, Eastern Utilities embarked on proactive communication efforts. Discussions with customers and community representatives centered around the following 6 points:

1. no viable tree will be removed unless requested by its owner or the designated community representative
2. structurally unsound trees are a potential hazard to a public roadway and financial liability to the community
3. win-win collaboration will mitigate mutual hazards to the power lines and public roadways
4. the percentage of trees removed is a very small portion of the total tree population
5. storm-proof pruning can improve the health and aesthetics of a tree
6. Eastern Utilities is committed to the renewal of the urban forest through tree planting.

## Conclusions

The utility arborist must justify tree management costs based on the impact of the expenditure on electric service reliability. Within utility urban forestry, the industry-accepted principle of maintaining clearances between trees and power lines on a multiple-year cycle is a cost effective strategy for minimizing outages. Large-scale outages, in terms of the number of customers affected and costs to restore electricity, are most often the result of tree or limb failure on the 3-phase portion of the primary circuits of the distribution network. Preventable outages can be minimized from trees that have a high probability of root, trunk, or limb failure by removing severely defective trees or storm-proofing trees with less severe defects.

Eastern Utilities has made programmatic adjustments to its Tree Management Program. Line clearance tree trimming will continue to be the main component of the program. The Danger Tree Mitigation Project—the removal of structurally un-

sound trees and performing storm-proof pruning—has reduced Customer Outage Hours from tree failure by 20% to 30% on the primary electrical circuits where it has been implemented. Proactive communication efforts have been crucial to getting the project started and gaining acceptance from within the communities.

The Danger Tree Mitigation Project can actually improve the overall health and management of a street tree population for the following reasons:

1. the trees removed represent a small percentage of the total population
2. tree-related hazards along roadways have been mitigated
3. storm-proof pruning can extend the life of a tree
4. resources have been shared between the communities and Eastern Utilities
5. renewal is increased through cosponsored planting.

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**Résumé.** Afin de développer une base de données statistiques des facteurs de pannes causés par les arbres, 14 entreprises de services électriques des États-Unis et du Canada ont travaillé avec Environmental Consultants, Inc. sur un projet de recherche des Causes d'interruption par les arbres. L'étude des interruptions s'est bâtie à partir d'une enquête de collecte et d'analyse de données en rapport avec des événements ayant causé une interruption de service causée par des arbres. Les résultats intérimaires fournissent des appuis en faveur de l'élagage cyclique de base de la croissance dans le but de minimiser le nombre d'interruptions imputables aux arbres.

**Zusammenfassung.** 14 Versorgungseinrichtungen in den USA und Canada arbeiten zussamen mit einem eingetragenen Umweltgutachterbüro in einem Forschungsprojekt über Unterbrechungen der Versorgungsleitungen, die durch Bäume verursacht wurden. Es soll eine Datenbank entwickelt werden, die auf statistischer Grundlage die Faktoren der Versorgungsausfälle erfasst, die mit Bäumen in Zusammenhang stehen. Die Störungsstudie besteht aus einer Erhebung, um die Daten von individuellen baumbezogenen Störungsereignissen zu sammeln und zu analysieren. Die vorläufigen Ergebnisse unterstützen die Forderung nach regelmäßigen Rückschnitten, um die Anzahl der Störungen, die durch Bäume verursacht werden, zu minimieren.