Reliability Based Vegetation Management Through Intelligent System Monitoring

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Project T-27 Tele-seminar, October 16, 2007
Reliability Based Vegetation Management Through Intelligent System Monitoring

Vegetation Management Basics:
• Trees are known to be a major factor affecting power system reliability.
• Trees can cause public safety hazards, including downed conductors.
• Vegetation management is largest cost in many utilities’ budget.
• $7-10 billion business annually
• Trim schedule generally is based on time, not on actual need, resulting in inefficient trimming.
Outages can be grouped into three classifications: Non-Vegetation Related, Vegetation related outages caused by hazard trees outside the right of way, and Vegetation related outages caused by trees inside the right of way.

(Hypothetical Example)
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The rate of Non-Hazard Vegetation outages remains relatively low immediately after a feeder is trimmed, then increases precipitously after several years.

(Hypothetical Example)
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Project Objectives:
- Relate measured tree-contact levels to reliability indices
- Provide information to assist in developing customized trimming schedules
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How trees cause outages:
• Hazard trees
• Trees contacting primary conductors
• Trees in customer secondary
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How trees cause outages:

• Hazard trees
  – Hazard trees exist outside the utility’s right of way
  – Cannot be trimmed
  – Generally cause outages by tearing down lines, creating outages of extended duration.
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How trees cause outages:

• Trees in customer secondary
  – Cause of a significant number of vegetation related outages
  – Affect a relatively small number of customers
  – Generally cause electrical events through mechanical means (push conductors together, break conductors, etc).
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How trees cause outages:

• Trees contacting primary conductors
  – If only one conductor is contacted, the fault path through the tree to earth results in a low voltage gradient and “high” impedance
  – If trees bridge multiple conductors, higher voltage gradient combined with lower impedance eventually leads to a high-current event.
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Through Intelligent System Monitoring

When a branch spans the two conductors, scintillation begins as localized heat begins to char and carbonize the wood, making it more conductive.

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The scintillation continues, forming carbonized paths along the branch, starting from each end.

These paths eventually meet, forming a continuous low-impedance path across the branch.

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The carbonization may proceed under the bark as well, causing the release of steam, dehydrating the wood underneath.
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When the carbonized paths meet and a low impedance path is formed, a high current event occurs.
Related Project:
Distribution Fault Anticipation

Distribution Fault Anticipation project
• Texas A&M University project with EPRI
• Sensitively monitors electrical and other data from operating feeders.
• Records and classifies high-fidelity event waveform data.
• Provides data for current PSERC project
Real-World Example: Vegetation Contact Burns Line Down

RMS waveform captures from a monitored feeder on November 2 and 3, 2004 show overcurrent faults that were caused by a tree in contact with an overhead line.

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Real-World Example: Vegetation Contact Burns Line Down

Tree contact tripped recloser intermittently 17 times over 24-hour period. Line eventually burned down, leaving 140 customers without service for 68 minutes, thereby affecting vegetation-related SAIDI, SAIFI, etc.

<table>
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<tr>
<th>Date</th>
<th>Time</th>
<th>Recloser Trips</th>
</tr>
</thead>
<tbody>
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<td>06:57:47</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>07:58:33</td>
<td>2</td>
</tr>
<tr>
<td>11/03/2004</td>
<td>00:09:06</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>00:16:48</td>
<td>1</td>
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<td></td>
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<td>01:15:30</td>
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<td></td>
<td>03:24:47</td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>06:19:45</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total Trips</strong></td>
<td></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>
Reliability Based Vegetation Management
Statistical Analysis

- Utility outage logs were analyzed dating back to 2000. Trees in this area were trimmed in the summer of 2003. For one particular 32-feeder substation, the vegetation-outage frequency was as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Outages</th>
<th>Storm Condition</th>
<th>(Total-Storm) Outages</th>
</tr>
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<tbody>
<tr>
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<td>30</td>
<td>6</td>
<td>24</td>
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<td>2005</td>
<td>17</td>
<td>7</td>
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<td>2</td>
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<td>24</td>
<td>11</td>
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<td>29</td>
<td>3</td>
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<tr>
<td>2000</td>
<td>39</td>
<td>19</td>
<td>20</td>
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</table>

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Reliability Based Vegetation Management
Statistical Analysis

Observations:
• From 2001-2004, the number of outages remained relatively constant, after storm activity was removed
• Lowest number of outages was 2002, the year before trees were trimmed
• Potentially possible to extend 48-month trim cycle without adverse reliability effects.
• Data only from one trim cycle, one substation, one utility
• Additional contributing factors (e.g. weather, customer activity, institutional reporting practices) are unknown.

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The majority of vegetation outages in the observed period disrupted very few customers. In spite of this, vegetation-intrusion caused a disruption to over 1000 customers at least once a year, on average.

Outage frequency vs. number of customers affected 2000-2006, 32-feeder substation.
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Statistical Analysis

Observations:

- 94 vegetation related outages (54.9%) affected 10 customers or less
- During the seven year monitoring period, an average of 0.76 events per feeder per year was observed.
- After removing outages affecting less than 10 customers, an average of 0.34 events per feeder per year (one event every three years) was observed.
Reliability Based Vegetation Management Experimentation

- Researchers staged experiments to determine feasibility of electrical detection at remote substation
- Branches of varying species and diameters used
- Waveforms, photographs, and video recorded.
Reliability Based Vegetation Management Experimentation

Experiment 1

- Crape Myrtle, approximately 0.75” diameter
- Carbonization continued in high-impedance state for 4 minutes, 38 seconds.
- Arcing sustained approximately 27 seconds before fuse operation
- 18 arcs of approximately 15 cycles, followed by 1 arc of approximately 172 cycles
Reliability Based Vegetation Management Experimentation

Experiment 1

• Fuse was replaced and line re-energized.
• Arcing resumed immediately and lasted approximately 5 seconds before second fuse operation.
• Fuse replaced a second time and line re-energized.
• Arcing resumed immediately and lasted an additional 4 seconds before third fuse operation.
• Arcing likely to continue with further energizations until tree burned itself in half.

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Reliability Based Vegetation Management Experimentation

RMS Neutral Current from Experiment 1 Arcing Event

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Researchers inspected the line and branch for damage caused during the arcing events.

Both the branch and line suffered significant damage as a result of the arcing episode.
Damage is clearly evident on both the line and branch in this photograph, showing the branch contact point with the neutral conductor. While the neutral conductor remains intact, its mechanical integrity has likely been degraded.
Damage to the branch near the point where the carbonized paths met. The bark is clearly seen peeled back from the wood.
Reliability Based Vegetation Management Experimentation

In addition to the line and branch, arcing damaged one of the insulators supporting the line. While the insulator was not new, photographic evidence from before the trial confirms this damage occurred as a result of this experiment.
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Conclusions:

• Regular, well designed trim cycles appear effective in minimizing vegetation-related events on distribution feeders.

• Vegetation intrusion produces electrical signals that are measurable from a remote substation.

• Field experiments conducted during the project provide valuable insight on the progression of vegetation-related fault conditions.
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Recommendations for future work:

• Extended trim times to determine at what point vegetation-related outages increase significantly
• Increase in the overall number of monitored feeders to obtain a significant number of representative events
• Extended monitoring window including multiple trim-cycles to study long-term behavior