The Wind-Speed Dose-Response of Tree-Falls Impacting the Transmission Grid of Southwest British Columbia

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Introduction

Talk Outline:

• Brief commentary on power grids and windstorms

• Methods

• Wind-related outages on the transmission grid (BCTC) around Metro Vancouver

• Wind-related outages on the distribution (BC Hydro) grid around Metro Vancouver

• Summary

Near Junction City, OR, 08 Feb 2002. All photos in this talk by the presenter.
Introduction

A thought:

• A transmission or distribution grid can be seen as a giant weather sensor

• Power-outage data (time, location) conveys useful information about storms impacting the grid
Introduction
The Columbus Day Storm (Freda) of 1962
CYVR U2A Strip-Chart Trace

- Extratropical cyclones sometimes bring extreme winds to BC
- High winds tend to impact the power grid
- For this storm, maximum wind and gust occurred between 23:30 and 23:40
- Max 2-minute wind was approximately 91 km/h around 23:35
Introduction

Brief Summary of Methods

• Isolated all circuits within a 50-km radius of the Vancouver International Airport (CYVR)

• Examined the relationship between tree-related outages and wind speed (wind and gust)

• Used the hourly weather record at CYVR: Noted all significant weather that may have occurred near time of outage (e.g. heavy rain, snow, wind, wind shifts)

• Depending on analysis, events with significant snow and rain were eliminated
Section 1: Transmission-Line Sensitivity to High Wind
BC Transmission Grid Response to Windstorms

The BCTC Outage Dataset

Pros:
- Data covers a broad enough period of time to include many weather events
- Precise timing of outage helps with determination of storm-related causes

Cons:
- Transmission lines are concentrated along narrow corridors, limiting the spatial area covered
- Transmission lines not impacted by trees very frequently even in major storms, resulting in limited outage data for each storm event
Essentially no relationship

Lack of relationship also present with wind (as opposed to gust)

Problem with relationship: A single impacted line can result in few or many customers affected

This preliminary: A maximum likelihood approach such as Poisson regression would likely be more informative for all of the regression analyses presented here.
• Essentially no relationship
• Lack of relationship also present with wind (as opposed to gust)
• Problem with relationship: Few circuits are hit in most storms—a single number (1) dominates, making linear correlation poor
BC Transmission Grid Response to Windstorms

Vancouver-Area Transmission-Grid Response (50 km Radius of CYVR) to All Windstorms 1990-2008 for Tree-Related Outages

- Marked jump in outage probability around 70 km/h
- At speeds above 80 km/h, outage probability appears to reach 75%
- Note the low number events at higher wind speeds
Section 2: Distribution-Line Sensitivity to High Wind
The BC Hydro Outage Dataset

Pros:
- Widespread, dense network providing good coverage in many areas
- Often many outages during significant weather events, providing a wide range of numbers useful for correlation
- Precise timing of outage helps with determination of storm-related causes

Cons:
- Short time period of dataset, 2005-2009, limits the number of storm events to be examined
Given what is being measured, a R-squared of 0.52 is encouraging.
For W-WNW windstorms, the R-squared is 0.63 (N = 63).
For SE windstorms, the R-squared is 0.71 (N = 34).
A multivariate analysis is planned, using a number of stations around YVR.
For all wind directions
Even fairly typical winter storms (wind 40-49 km/h) tend to produce a high frequency of outages
At roughly 60 km/h, outage probability is approximately 100%
BC Hydro Power-Grid Response to Windstorms

For All W (200-320°) Wind Events With Peak Wind >40 km/h at the Vancouver International Airport, Number of Events Associated With a Power Outage on Vancouver-Area BC Hydro Lines, Oct 2005-Aug 2009

- W-WNW events have similar pattern to all events
- At roughly 60 km/h, outage probability is approximately 100%
BC Hydro Power-Grid Response to Windstorms

For All SE (090-190°) Wind Events With Peak Wind >40 km/h at the Vancouver International Airport, Number of Events Associated With a Power Outage on Vancouver-Area BC Hydro Lines, Oct 2005-Aug 2009

- SE events reach 100% outage probability 10 km/h below W-WNW events
- SE events also do not tend to produce wind speeds as high as W-WNW events
BC Hydro Power-Grid Response to Windstorms

SE vs. W-WNW: Why different?

- W-WNW winds have long overwater fetch, supporting higher speeds at the airport

- SE winds as measured at the airport are probably better representative of much of Vancouver Metro than W-WNW winds

- When looking for correlation, it is critical to understand such differences: Mixing W-WNW and SE events reduces correlation (e.g. 0.52 vs 0.63 and 0.71)

Satellite image courtesy Google Maps.
Summary

For tree-related power outages on circuits within 50-km of CYVR:

- The correlation between wind and gust speed at CYVR and the magnitude of transmission-line (BCTC) outages is very low ($R^2$ around 0.05)

- However, there appears to be a threshold of 70 km/h wind where the probability of a transmission line failure climbs rapidly

- The correlation between wind speed at CYVR and magnitude of distribution-line (BC Hydro) outages is moderate ($R^2$ around 0.52-0.71)

- At a wind speed threshold around 60-69 km/h, the probability of an outage on BC Hydro lines approaches 100%

- For these kinds of analyses, it is useful (essential) to pay attention to wind direction
Questions & Comments
(Thank you)

Near Seaside, OR, 04 Dec 2007.