Vegetation Impact Analysis

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1 Introduction

This document proposes a tree fall analysis model for HiPAS GridLAB-D in support of the grid resilience use-case.

2 Background

Grid resilience is affected in part by vegetation contacting or falling onto power lines during significant weather events. GridLAB-D can model the probability of vegetation events using simplified models that can scale easily based on the pole vulnerability method implemented for wind analysis in the DOE Grid Resilience Intelligence Platform (GRIP).

3 Methodology

The impact of vegetation on power lines stems from two kinds of wind-driven events: (1) vegetation contact with lines, which results in a fault, and (2) vegetation fall onto lines, which results in an outage. In GridLAB-D a fault results in a momentary loss of service, where momentary is defined according to IEEE Standard 1366, i.e., lasting less than 5 minutes. An outage is a non-momentary loss of service, i.e., lasting 5 or more minutes.

3.1 Vegetation Contact

Vegetation may contact when it has have grown into the right of way enough to contact an uninsulated power line when the wind blows hard enough to cause both to deflect sufficiently. Thus the following factors must be considered:

1. Wind speed, V (ft/s)
2. Right-of-way distance, D (ft)
3. Vegetation growth rate, R (ft/y)
4. Elapsed time since right-of-way was maintained, Δt (y)

5. Vegetation susceptibility as wind speed increases, S (s)
6. Line length, L (ft)

Vegetation contact with the lines is possible given deflection in both sagging lines and susceptible vegetation. When the sum of the two deflections exceeds the open space between the vegetation and lines, then momentary contact becomes probable.

The deflection of sagging power lines as a function of wind speed, line length, and air temperature is approximated as

$$D_L = y \ \sin\left[\tan^{-1}\left(\frac{w}{F_W}\right)\right] \tag{1}$$

where y is the observed line sag at the midpoint between the poles, w is the line weight in N/m, and the perpendicular wind force in N/m is

$$F_W = d \ \beta \ V^2 \tag{2}$$

where d is the line diameter in meters, and the β is the line windage coefficient in s/m^2.

The deflection of vegetation as a function of susceptibility and wind speed is approximated as

$$D_V = S \ V \tag{3}$$

The open distance between the line and vegetation is approximated as

$$D_O = D - R \ \Delta T \tag{4}$$

The probability of contact is determined by the ratio

$$P_C = \begin{cases} \frac{D_L + D_V}{D_O} & : \quad D_O > 0 \\ 1.0 & : \quad D_O \leq 0 \end{cases} \tag{5}$$

When the ratio $R_C \geq 1.0$ then contact with an uninsulated power line is certain and will cause a momentary fault.

3.2 Vegetation Fall

Vegetation may fall onto power lines when it has aged sufficiently and is stressed due to drought. Vegetation must have grown into the right-of-way so that the probability of fall is function of

$$R_F = \frac{D_O}{D} \tag{6}$$

and the critical wind speed V

$$V_C = \frac{100 - A}{5} + 10 \tag{7}$$

where A is the age of the tree [**?**]. The probability of a line outage from vegetation fall is thus

$$P_F = \begin{cases} R_F \frac{V}{V_C} & : \quad V \geq V_C \\ 0.0 & : \quad V < V_C \end{cases} \tag{8}$$

References