SafeBuild: The Risk-Based Utility Pole Design Software

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***Abstract*— On a yearly basis, California experiences fires, property damage, and prolonged outages due to the failure of electric utility infrastructure. In 2007, a Southern California Edison (SCE) pole broke, igniting the Malibu Fire. In 2011, in the San Gabriel Valley, 248 SCE poles broke, causing an outage to 440,000 customers for up to a week. In 2018, a component on a PG&E tower broke, igniting the *Camp Fire*, which destroyed 18,804 buildings and killed 86 civilians. These structural failures were due, in part, to the utility's failure to calculate the probability that its poles and towers could withstand known local wind speeds without breaking. Existing pole design software, SPIDAcalc and Osmose O-Calc, have major flaws. They provide inaccurate wind modeling analysis due to their failure to account for material strength variability. Additionally, the software calculates a strength factor using a Reference Wind Load, which is of little practical value as it cannot be compared against known local wind speeds. The current research corrects these errors by introducing a program, SafeBuild, that, given a wind gust, provides the probability that a structure can withstand the wind gust without breaking.**

I. INTRODUCTION

In California, failures of overhead electric distribution facilities have caused numerous wildfires, outages, and property losses. In 2007, an overloaded Southern California Edison (SCE) pole broke, igniting a fire that destroyed 14 structures. In 2011, in the San Gabriel Valley, 248 SCE poles broke, causing an outage to 440,000 customers, some for as long as a week. In 2018, a deteriorated component on a Pacific Gas & Electric Company tower broke, igniting the *Camp Fire*, which destroyed 18,804 buildings and killed 86 civilians. In these cases and others, all of which occurred during windy conditions, the cause of the incident was attributed to the utility's failure to design its facilities to withstand known local wind speeds. In the case of poles, the design software used by utilities (e.g., SPIDAcalc and Osmose O-Calc) have a major flaw: the software calculates the pole's safety factor by dividing the pole's bending moment resistance by the bending moment due to a Reference Wind Load. This method treats the safety factor as a strength factor, which underestimates the bending moment due to lateral loads, i.e. the P-Δ effect. In other words, the current method underestimates the true bending of the pole due to wind. Indeed, General Order 95 – the California statute governing the design of overhead facilities – requires the safety factor to be treated as a load factor (instead of a strength factor), which will properly account for the P-Δ effect. Furthermore, the method is misleading because the bending moment resistance of the pole is calculated using the median wood fiber strength; as a result, there is a 50% chance that the pole is weaker than the utilities assume. Finally, the method is misleading because safety factors obfuscate the actual windspeed that a pole should be able to withstand. For example, a very clear result such as "this wood pole can withstand a 112 mile per hour wind gust with a 95% probability of success" is not achievable via the existing software. Instead, the software provides that at some Reference Wind Load (such as 8 pounds per square foot), the pole has some strength factor (a value of 4, for example). This result has limited practical value and cannot be compared to known local wind speeds. The current research developed a structural design software, SafeBuild, that improves upon existing software: for any wind gust inputted by the user, SafeBuild calculates the probability that the pole can successfully withstand the wind gust based on the inherent material strength variability of wood. Note that, while SI units are the staple in most fields, SafeBuild uses US Customary Units, as this is the industry standard. SPIDAcalc and Osmose O-Calc also use US Customary Units.

II. METHODS

SafeBuild's methodology can be broken into several steps: (1) the engineer designs a utility pole using a spreadsheet; the design includes the pole class (from which the pole's groundline circumference C_G and pole top circumference C_{TOP} can be obtained) and wood species; the design also includes data for all supported conductors and equipment, e.g. a transformer; (2) the engineer enters a wind gust in miles per hour (mph) and then initiates the calculation; (3) SafeBuild converts the wind gust into a wind load, in pounds per square foot, and applies the wind load to all exposed surfaces; (4) using Finite Element Analysis, SafeBuild calculates the total bending moment BM_{TOTAL} at the pole's groundline due to the applied wind load; (5) SafeBuild calculates the probability that the pole can withstand the wind gust by determining the z-score z related to the bending moment resistance of the pole, taking into account the median wood fiber strength $F_{b,\ median}$ and its coefficient of variation CV (≈ 0.2 for wood).

While SafeBuild's Finite Element Analysis method is standard within the industry, its probability calculation is uniquely used. The calculation for finding z for the bending moment resistance of the pole is as follows:

$$\mathrm{BM_{TOTAL}} = 0.000264\ (\mathrm{F_{b,\ median}})(1 - \mathrm{z^{*}CV})(\mathrm{C_G}) \qquad (1)$$

The value of z is iterated until (1) becomes true. Once z is known, a table of z-scores can then provide the probability that the pole can withstand the wind gust.

III. EXPERIMENTAL DESIGN AND RESULTS

Using SafeBuild, a hypothetical utility pole was wind loaded in three trials. The pole had a length of 50 feet (ft), with 6 ft underground. The groundline circumference C_G and pole top circumference C_{TOP} was 35.72 inches and 21.59 inches, respectively, with a linear taper. The pole supported the facilities shown in Table I. For Trial 1, the pole is made of Red Cedar ($F_{b,\ median}$ = 5800 lb_f/in^2) and the wind gust is assumed to be 112 mph. The results, shown in Fig. 1, show that the pole has an 8.69% chance of withstanding the wind gust. For Trial 2, the pole is made of Douglas Fir ($F_{b,\ median}$ = 8000 lb_f/in^2) and the wind gust remains 112 mph. The results, shown in Fig. 2, show that the pole has a 67.36% chance of withstanding the wind gust. For Trial 3, the pole is made of Douglas Fir and the wind gust is lowered to 92 mph. The results, shown in Fig. 3, show that the pole has a 97.13% chance of withstanding the wind gust.

TABLE I. CONDUCTORS AND EQUIPMENT SUPPORTED ON THE EXAMPLE POLE

Conductor Attachments						
Left Span Length[a]	***Right Span Length***	***Diameter***	***Height***[b]	***Weight or Density***	***No.***	***Type***
400 ft	300 ft	0.25 in	44 ft	0.2 lb/ft	3	Wire
400 ft	300 ft	0.50 in	33 ft	0.5 lb/ft	1	Wire
400 ft	300 ft	0.75 in	24.5 ft	1 lb/ft	1	TV cable
400 ft	300 ft	0.50 in	20.3 ft	0.5 lb/ft	1	Phone cable
Equipment Attachments						
0	0	0	37.5 ft	600 lb	1	XMFR

a. Span Length represents the length of the conductor span to the left or right of the pole.

b. Height represents the attachment height of the conductor or equipment on the pole.

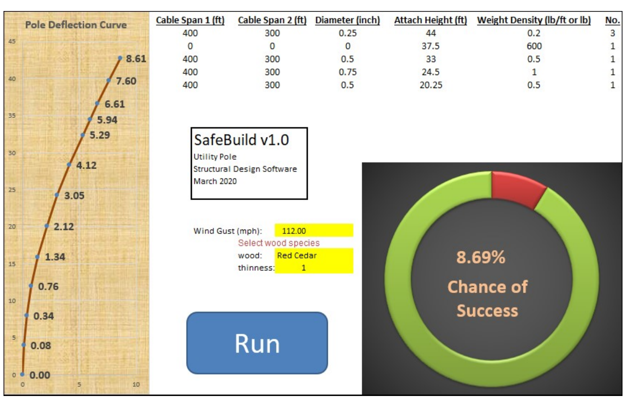

Figure 1. First trial: the pole has an 8.69% chance of not breaking.

Figure 2. Second trial: the pole has a 67.36% chance of not breaking.

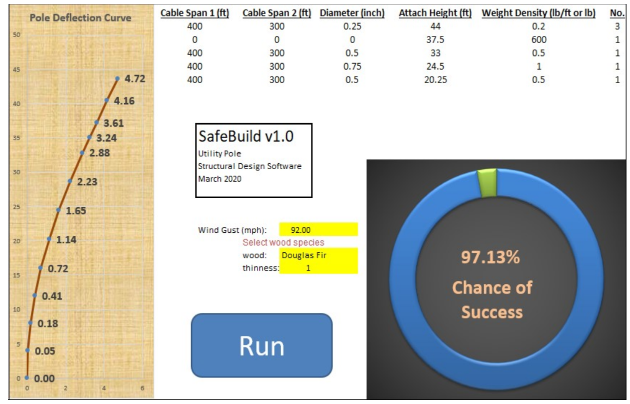

Figure 3. Third trial: the pole has an 97.13% chance of not breaking.

IV. DISCUSSION

Current pole design tools calculate a pole strength factor based on a Reference Wind Load (which is typically a blanket value applied indiscriminately). However, strength factors have limited practical value because they cannot be compared against known local wind speeds; instead, an engineer can only discern that a pole with a higher strength factor is stronger than a pole with a lower strength factor. SafeBuild takes a completely different approach. Instead of spitting out a pole strength factor, SafeBuild calculates the probability that a pole can withstand a given wind gust. This means that SafeBuild can be used to design an overhead electric system using a risk-based methodology. For example, an engineer can use SafeBuild to design any pole to have a 99% probability of withstanding the greatest 50-year wind gust in a given area. SafeBuild can prevent utility poles from being underbuilt, thereby enhancing public safety; at the same time, SafeBuild can prevent utility poles in low wind areas from being overbuilt, thereby saving ratepayer money. Therefore, it is worth further exploring SafeBuild.

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