Estimating Damage to Electric Power Distribution Caused by Hurricanes using the Hurricane Electrical Assessment Damage Outage Tool (HEADOUT)

Prepared by
Leah Talaber, Steve Folga, Brian Craig, Edgar Portante, Alice Lippert and Eric Rollison

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Background - Hurricane Tool

- All Atlantic and Gulf of Mexico coastal areas are subject to tropical cyclone/hurricanes.
- The Atlantic hurricane season lasts from June to November, with the peak season from mid-August to late September.
- Quick turn around tool for Federal Agencies.
- Emergency Response and Deployment of Resources
- Speed and Accuracy of Analysis is Important
- Restoration time NOT explicitly considered
Background - Hurricane Tool

- The National Hurricane Center (NHC) monitors tropical cyclones
- Forecast/Advisories are issued on all Atlantic and eastern Pacific tropical and subtropical cyclones every six hours
  - Dataset for storm tracks in shapefile and kml/kmz formats
- HURREVAC creates 72-hour wind swath based on NHCs Advisory Wind Fields

Sources: HURREVAC and NOAA
Methods - Wind Damage & Electric Losses

- Collect data from NOAA Advisory through HURREVAC as Tropical Cyclone makes landfall
  - Maximum gust wind speeds, track and 72-hour wind swath (74, 58, and 39 mph)
- Apply contouring method developed to estimate wind speeds by interpolating:
  - Spatial analyst tool provides a continuous surface for which wind contours are created using the HURREVAC wind swath data. Contours are created from this raster file.
  - Apply fragility curve to produce damage fraction as a function of wind speed.
- Overlay wind speed swaths over Census population data:
  - Estimate number of people per wind swath
  - Determine as a function of State
  - Determine households at-risk of electric outage by multiplying number of people in each swath by damage fraction
**Methods - Wind Damage Flow Diagram**

Part 1

- **Gather Data**
  - NOAA's National Hurricane Center (NHC) / HURRVEC
  - • 72-hour projected path
  - • 3 Intervals: 74, 58, 39 mph
  - • Max. center wind speed

- **Interpolate**
  - Continuous Surface
  - • Natural neighbor technique

- **Contours**
  - User-Defined Intervals
  - • Intervals of wind speed
  - • Smooth contour lines

- **Apply Fragility Curve**
  - Pre-defined Tables
  - • Join to fragility curves
Methods - Estimate Customers Affected

Select Census Tract Data

- Census Tracts shapefiles contain pre-populated information using 2010 Census data

Split based on Damage Curve

- Create feature class for census tracts that intersect contours
- Assume dispersed distribution of customers through census tract

Calculate Households Impacted

- Estimated Electric Customers without Power = \((\text{New Area} / \text{Tract Area}) \times \text{Number of Households} \times \text{Percent Damage}\)
Fragility Functions/Curves

- Fragility curves are the cumulative distribution function of the capacity of the asset to resist a particular undesirable event. Curves developed are the damage fraction of customers impacted by wind speed.

- Development of fragility curves:
  - Curve #1 – Commonly Used Curve; Five damage fractions applied
  - Curve #2 – ANL Developed Fragility Curve; Interpolation of five damage fractions
  - Curve #3 – ANL Developed; Based on data showing county level impacts
Testing Fragility Curves

- Testing Fragility Curves using data from DOE Situational Reports (SitReps):
  - DOE Situation Reports available for 21 tropical cyclones, dating back to 2003.
  - 17 of those 21 events made landfall and contained usable data.

- NOAA Advisories for the tropical cyclone as it made landfall are compared to the SitReps
  - Delay times for utilities to report the affects were taking into account

<table>
<thead>
<tr>
<th>Storm</th>
<th>Year</th>
<th>Processed</th>
<th>Region</th>
<th>Area</th>
<th>Landfall State</th>
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Notes: (3) All three fragility curves were tested; (1) Only Walker Fragility Curve was tested; N/A - Storm did not make landfall

- All three fragility curves were tested for the following events:
  - Isaac 2012 (Louisiana)
  - Sandy 2012 (New Jersey / New York)
  - Ike 2008 (Texas)
  - Dolly 2008 (Texas)
  - Gustav 2008 (Louisiana)
Results: Comparing 3 Curves

- Curve #1 and #2 are more than double the number of reported customers impacted in three of the five cases.
- Curve #3 is the most accurate and therefore tested for the remaining cases.

Examining Results by State

- DOE Situational Report states, “combined total peak customer electricity outages from Hurricane Sandy was 8,511,251.”
  - Timing of reporting is not exact
- Curve #3 is most consistent with SitReport
  - Inconsistencies at a state level, however, there may be discrepancies in reporting if utilities are multi-state
Results: Fragility Curve #3

- Curve #3 was tested for 17 of those 21 events where SitReports were available
  - Nine Gulf Coast storms,
  - Four Atlantic Coastal; and
  - Four impacting the State of Florida.

- Three of the four Florida cases, produced accurate results
  - Simulation for Jeanne (2004) overestimated the outages. However, portions of Florida were affected by Hurricane Ivan only nine days prior.

- Largest discrepancy produced for Irene, partially due to variances in the NOAA forecast.
  - The intensity decreased as Irene moved up along the Atlantic Coast—sustaining max wind speeds of 75 mph opposed to the 90 mph wind projections.

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Notes: N/A - Storm did not make landfall
Discussion

Numerical Results:
- Projected results using Curve #1 and #2 are very poor relative to the DOE Situation Reports
- Each storm is unique with each being viewed as a case study
  - As seen with Jeanne (2004) and Irene (2012)
- Discrepancies between the reported and simulated numbers can occur
  - Utilities estimate the number of outages based on customer phone calls and physical inspection
  - Numbers may not be reported to DOE/OE in an accurate or punctual manner.

Model Outcome:
- A benefit of this tool is that the damage curves can be easily modified.
  - Provides ability for empirical analysis to test fragility curves
- Produces results quickly and can be recreated.
  - On average, it takes 5 minutes to run, down from 4 hours
- Documentation of steps means consistency so that multiple users can perform the same work.
- Results are reproducible
Future Developments

- **Automation**
  - Save files directly from NOAA to minimize user interaction with tool

- **Refined fragility curve**
  - Examine the impacts by county and utilities where data is available
  - Test and refine results for different regions in the U.S. if necessary

- **Determine key factors that may influence damage by area**
  - Whether utilities maintain underground distribution lines
  - Implementation of Hardening / Design Standards
  - Vegetation
Limitations and Recommendations

- Electrical distribution details are not available.
  - Data is proprietary and typically closely held by the utility owners.
  - Above verses underground, wooden verses metal poles, etc.

- Estimate customers base on household information. Does not include information on the number of commercial and/or industrial customers.
  - Examine impacts by utilities

- Hardening practices vary on a utility-by-utility basis.
  - May have to develop multiple generic fragility curves based on hardening practices for a region.

References and Acknowledgements

References


Acknowledgements

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Questions or Comments?

Thank you!