Electric Power and Transit Infrastructure Performance Models for Superstorm Sandy

Hurricane Sandy made landfall in the New Jersey-New York region on October 29, 2012. Storm surge was the primary culprit in damage to the civil infrastructure system as extensive flooding occurred through the region. In this paper, "civil infrastructure" refers to the eleven interdependent lifeline networks that are critical for the proper functioning of society, particularly in urban areas [Chang et al. (2005)]. These lifelines include electric power delivery, transportation, water supply and treatment. Governor Cuomo and Mayor Bloomberg both called for commissions to investigate widespread outages of power and transit that resulted from both the tropical cyclone of October 29th and the Nor'easter of November 7th, which comprised the so-called "superstorm". According to the hearings of the Public Service Commission as delineated in documents online available from http://documents.dps.ny.gov/public/MatterManagement, metrics to assess performance during extreme weather events, including the future effects of climate change, should be adopted for use by ConEd and other regulated utilities.

In our investigation we will present GIS-based storm surge, rainfall and wind speed data for the New York City region with a specific focus on Manhattan. The storm surge data are based upon FEMA maps available through http://184.72.33.183/GISData/MOTF/Hurricane%20Sandy/ with specific times series data collected by NOAA at the Battery Park facility in Manhattan, available at http://tidesonline.noaa.gov/plotcomp.shtml?station_info=8518750+The+Battery,+NY. The wind speed data are comprised of NOAA-based H*Wind maps. Limited joint probability distributions of the storm surge and wind speeds for the Battery Park location will be presented. Examinations of similar data at nearby locations will be made and compared to the Battery Park results. Rainfall data are based upon the tropical cyclone report provided by Blake et al. (2013). The spatial representations of the three primary loadings will be used to examine the salient features of the storm from a structural engineering perspective.

The storm data will be examined for correlations with power and transportation outages and recovery. The power outage analysis will be accomplished through the fitting of system fragility models as described by Reed et al. (2010) to outage and related structural damage data derived from reconnaissance by the authors, online sources, the Public Service Commission and the reports prepared by the City of New York in May and July, 2013, respectively [City of New York (2013), Gibbs and Holloway (2013)]. "Fragility" is an engineering measure to assess the probability of damage to a structural system for given loadings. In this instance, the loadings are the combination of storm surge and wind speed, so joint probability distributions of the two are important. Because most other infrastructure systems are dependent on power delivery for their recovery, we first focus on the electric power delivery system in this paper. Then, secondarily, we evaluate transportation outages and recovery rates over time for major transit facilities that were dependent on electricity though the specific linkage is not always available. For electric power outages, empirically-based in-situ resiliency models and storm-based reliability indices developed previously for hurricanes by Reed et al. (2009) will be evaluated for Sandy. For example, the reliability index STAIFI will be compared with the IEEE metric SAIFI [e.g., IEEE (2001)]. The results will be compared with those for other storm events. Recommendations for performance improvements such as system hardening and redundancy will be suggested.

References

Blake, Eric S., Todd B. Kimberlain, Robert J. Berg, John P. Cangialosi and John L. Beven II. (2013). *Tropical Cyclone Report: Hurricane Sandy*, Report Number AL182012, National Hurricane Center, 12 February.

Chang, S.E., T.L. McDaniels and D.A. Reed. (2005). "Mitigation of Extreme Events: Electric Power Outage and Infrastructure Failure Interactions," The Economic Impacts of Terrorist Attacks. Ed.

City of New York (2013). *A Stronger, More Resilient New York*, available from http://www.nyc.gov/html/sirr/html/report/report.shtml , July.

Gibbs, Linda I. and Caswell F. Holloway. (2013). *NYC Hurricane Sandy After Action: Report and Recommendations to Mayor Bloomberg*. May. available from http://www.nyc.gov/html/recovery/downloads/pdf/sandy_aar_5.2.13.pdf.

IEEE Guide for Electric Power Distribution Reliability Indices. (2001). IEEE Standard 1366, 2001 Edition.

Reed, D.A., K.C. Kapur and R.D. Christie. (2009). "Methodology for Assessing the Resilience of Networked Infrastructure." *IEEE System Journal*. Vol. 3. No. 2, June, pp. 174-180.

Reed, D.A., M. D. Powell and Julie Westerman, (2010) "Energy Infrastructure Damage for Hurricane Rita." *Natural Hazards Review* (ASCE), Vol. 11. No.3. August. pp. 102-109.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant Number(s) 1316290 (U. of Washington); 1316301 (Louisiana State University); and 1316335 (New York University) titled, "RAPID/Collaborative Research: Collection of Perishable Hurricane Sandy Data on Weather-Related Damage to Urban Power and Transit Infrastructure." Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.