Simulation Optimization for Operational Resilience of Interdependent Water-Power Systems in the US Virgin Islands.

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Cpt Dominik Wille, German Army | dominik.wille.gy@nps.edu | 831-238-2716

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In 2017, Category-5 hurricanes Irma and Maria made landfall on the US Virgin Islands (USVI) within two weeks of each other and destroyed infrastructure across the entire territory. Impacts were so severe that it took months for crews and utility providers to recover electricity and drinking water services back to normal operation [1]. Physical impacts of the hurricanes primarily affected the electricity system as extreme wind and rain ripped power poles out of the ground, destroyed transformers, and flooded critical equipment. Water distribution infrastructure largely survived the storms, yet the loss of electricity left the system inoperable and unable to pump water to customers. To prepare these systems for future disasters, a better understanding of their interdependent failure and protection is needed.

This work studies the water and power distribution systems on the island of St. Croix (STX) to predict the outcome of interdependent water-power failure events and recommend system hardening and protection activities. As the storms revealed, loss of electricity on STX can also lead to loss of pumping stations that distribute water. During these situations operators rely on water storage tanks to serve communities until electricity and pumps return to service. The goal of this thesis is to model how water-power failures happen and recommend ways to prevent them by answering the following questions:

- How do worst-case and hurricane induced blackouts affect STX pumping stations?
- How long can the STX water system provide services without electricity?
- In what ways can STX power infrastructure be hardened to support water distribution?

This research develops simulation optimization models for STX water and power distribution systems to predict interdependent failures [2]. We use an AC optimal Power Flow (ACOPF) model of the STX power distribution system to identify communities and pumping stations affected by hurricane failure scenarios. We relate results to a pressure driven demand (PDD) model of the STX water distribution system to measure which customers lose water when pumps lose electricity. We analyze results to determine how water operators can maximize water access during a blackout and identify how power system hardening can improve water resilience.

The current timeline for this project is:

- September 2019: Site visit to the USVI – model improvement and stakeholder feedback
- October 2019: Complete Water and Power distribution model
- November 2019: Complete failure analysis and recommendations
- December 2019: Site visit to USVI / Graduation – final presentation of model and results

This work is part of a bigger project in support of the Federal Emergency Management Agency (FEMA) studying interdependent power, water, roadway, and telecommunications infrastructure in the USVI [1]. Research is completed in cooperation with the US Department of Energy (DOE), the Naval Postgraduate School (NPS), the University of Virgin Islands (UVI), and USVI utility providers and authorities.

References:

1. Alderson, D.L, Bunn, B.B, Eisenberg, D.A, Howard, A.R, Nussbaum, D.A and Templeton, J.,„Interdependent Infrastructure Resilience in the U.S. Virgin Islands: Preliminary Assessment, Naval Postgraduate School Technical Report NPS-OR-18-005, 2018, December
2. Bunn, B.b, An Operational Model of Interdependent Water and Power Distribution Infrastructure System, M.S. Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, September 2018

Additional POC: Dr. Daniel Eisenberg (daniel.eisenberg@nps.edu);
Dr. David Alderson (dlalders@nps.edu)