

GRID RELIABILITY AND RESILIENCY INITIATIVES FOR THE ISLAND OF PUERTO RICO

MIDWEST ENERGY SOLUTIONS CONFERENCE
CHICAGO, ILLINOIS

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AGENDA & OVERVIEW

1. Impact of Hurricanes Irma and Maria on Puerto Rico Electric Power Grid

2. Energy System Transformation Plan

3. Grid Resiliency and Reliability Solutions

4. Islandable Grids and Microgrids

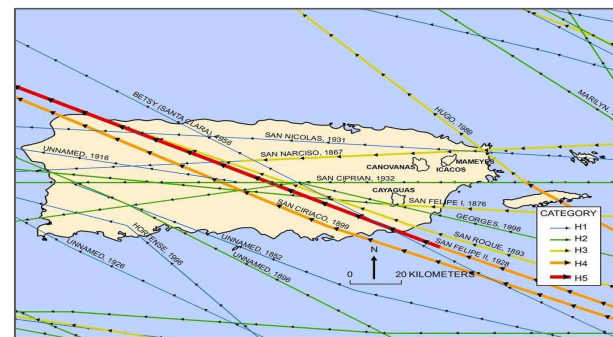
5. Summary and Q&A

IMPACT OF HURRICANES IRMA AND MARIA BACKGROUND

The electric power delivery system sustained extensive damage from Hurricanes Irma and Maria in September 2017.

Key factors:

- Successive Category 4 & 5 hurricane force winds landed within 2 weeks, devastating the grid
- Over 1 million customers (~80 percent) impacted by the storm, some up to 6 months without electric service
- Virtually all transmission and distribution lines, and most substations sustained damage, many extensively
- Recovery hampered by limited materials, transport challenges and reliance on crew support from mainland utilities
- Aging infrastructure increased susceptibility of T&D system to interruptions



Source: U.S. Geological Service



- Island lies within the path of several hurricanes over past decades
- Key power delivery assets damaged throughout the island

Source: New York Power Authority Damage Assessment Reports

CURRENT STATE OF PUERTO RICO ELECTRIC POWER GRID

Although most power generation and delivery systems have been repaired and are back in service, the grid remains susceptible to storm damage and widespread outages.

Challenges and deficiencies:

1. Most generating facilities are old and inefficient, burning high cost residual fuel oil. Less than 2 percent renewable generation
2. Load has declined by over 20 percent over the last decade, resulting in over 50 percent generating reserve margin
3. Over 80% of T&D system not designed and constructed to withstand to Category 4 winds
4. Many lines located in highly mountainous and rugged terrain, and susceptible to vegetation-related interruptions
5. Many substations located along coastlines and flood zones - significant water intrusion during storms
6. Limited automation, control, communications and operational technologies



Source: New York Power Authority Damage Assessment Reports

ENERGY SYSTEM TRANSFORMATION

GRID MODERNIZATION STRATEGY

The Government of Puerto Rico created an Energy System Organization (ESO) to develop a long-term plan to transform the electric power grid.

The plan is designed to achieve the following:

Repair and harden to current codes and standards in T&D for critical infrastructure and high risk areas

Decentralize generation and move to cleaner, more sustainable energy sources

Deploy islandable grids to increase grid flexibility and resiliency across the island

Transform IT/OT systems to enable operation distributed energy resources

Adopt and implement Emergency Preparedness Plan

Governor's Vision for Recovery:

“Transform the energy system to ensure customer-centric, affordable, resilient, reliable, and scalable electricity that incorporates more renewables, microgrids, and distributed energy resources (DER); can drive new businesses and employment opportunities; and can support residents’ well-being.”

GRID RESILIENCY AND RELIABILITY SOLUTIONS

PLAN COMPONENTS

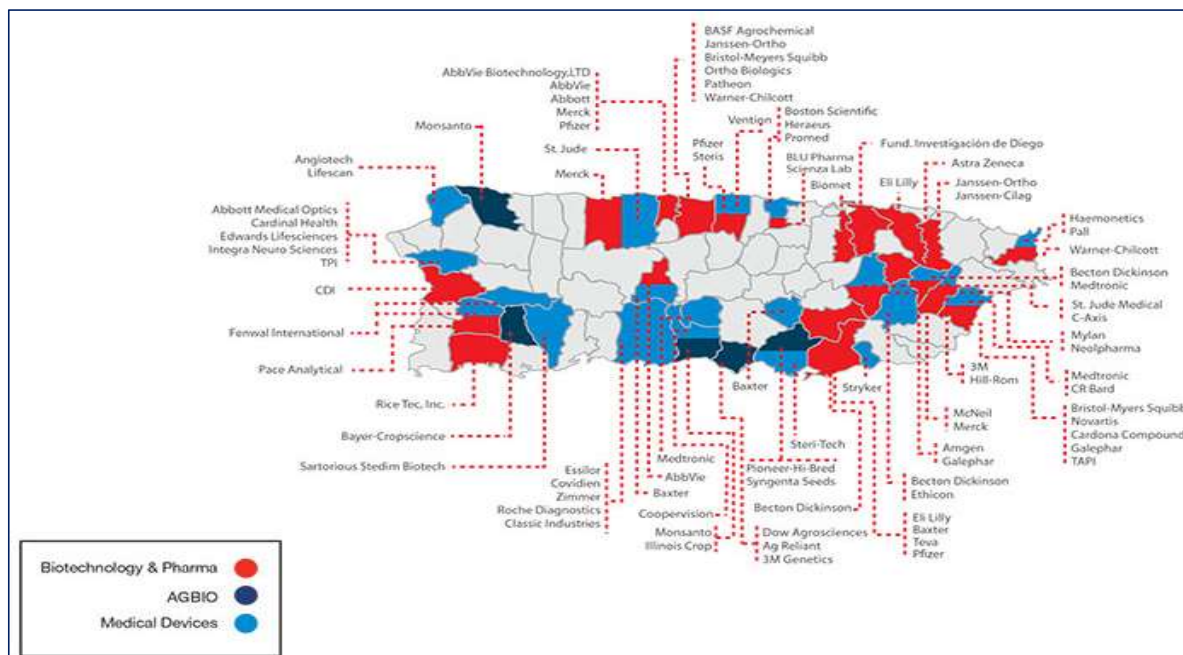
The grid modernization plan is comprised of 10 initiatives covering a broad cross-section of the power delivery system, generation assets and operations.

1. Transmission & Substations
 - Rebuild/Harden lines and substations to withstand Category 4 hurricanes
 - Relocate/raise substations located in flood-prone areas
2. Distribution
 - Rebuild/harden lines to withstand Category 4 winds
 - Greater automation (FLISR) & vegetation management
3. Generation & Fuel
 - Retire/replace generation with efficient natural gas units
 - Increase reliance on renewables and energy storage
4. DERs & Microgrids
 - Extensive Microgrids, demand response and efficiency
 - Islandable grids/minigrids
5. Technology Transformation
 - Upgrade/replace EMS/SCADA/OMS
6. Security
 - Focus on cyber and physical security
7. System Operations
 - New/upgraded control, security & Smart Grid diagnostics centers
 - New coms/control systems for islandable grid operation
8. Emergency Response
 - Enhanced emergency plans, facilities and spares
9. Regulatory & Policy
 - New codes and design standards
 - Streamlined DG interconnection procedures
10. Operational Efficiency
 - Enhanced asset management
 - T&D training for new technologies and standards

STRATEGY TO IMPROVE RELIABILITY AND RESILIENCY

CRITICAL LOADS

Continuity of electric supply is essential for both critical loads and major industries located across the island.



*Agricultural,
pharmaceutical and
biomedical industrial
plants located
throughout the island*

Source: Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico report

ISLANDABLE GRID DESIGN

“MINIGRIDS” PROPOSED TO IMPROVE RELIABILITY & RESILIENCY

Minigrids will be created for 8 “islands,” each with sufficient power generation to operate independently or in parallel with the contiguous grid.

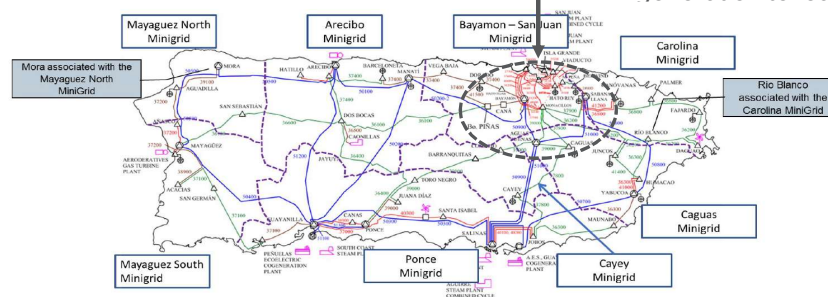


Each Minigrid:

- Capable of serving all essential loads (200 MW to 400 MW)
- Supplied by combination of combustion turbines, solar photovoltaic, and battery storage
- Equipped with local controllers for stand-alone operation
- Supplemented by Microgrids to serve remote loads



New lines and substations needed to reliably deliver generation to load centers.



Source: Siemens 2018 Integrated Resource Plan

SUMMARY

The Government of Puerto Rico has created an organization comprised of industry experts, federal agencies, national laboratories, and the local utility to achieve the vision set forth in its recovery plan.

Key Takeaways:

1. The transformation of the electric grid to one that is highly reliable and resilient is underway, but will take a decade or longer to complete
2. Significant upgrades to the transmission and distribution system are needed to bring it up to current design standards
3. Greater de-centralization of generation and creation of an islandable grid architecture provides for greater operating flexibility and reliability for all customers
4. Up to 50 percent of new generating sources renewable resources, mostly solar photovoltaic, needed to meet aggressive Renewable Portfolio Standards
5. Large amounts of energy storage, about 50 percent of the total amount of renewables, is required for reliability and system operations (e.g. ramping and frequency control)



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