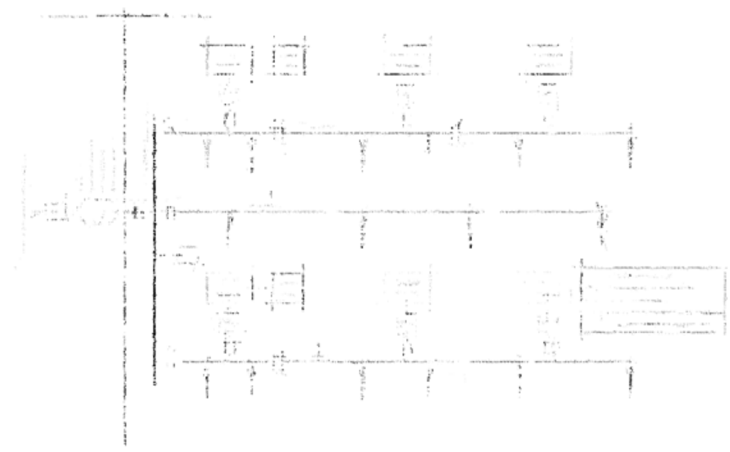


μ-grids Integration to the Puerto Rico Electric System

CCPR – Puerto Rico Energy Sector Transformation
Condado Plaza Hilton – San Juan PR

Carlos A. Reyes- Berrios, P.E.
April 19, 2018

Objectives

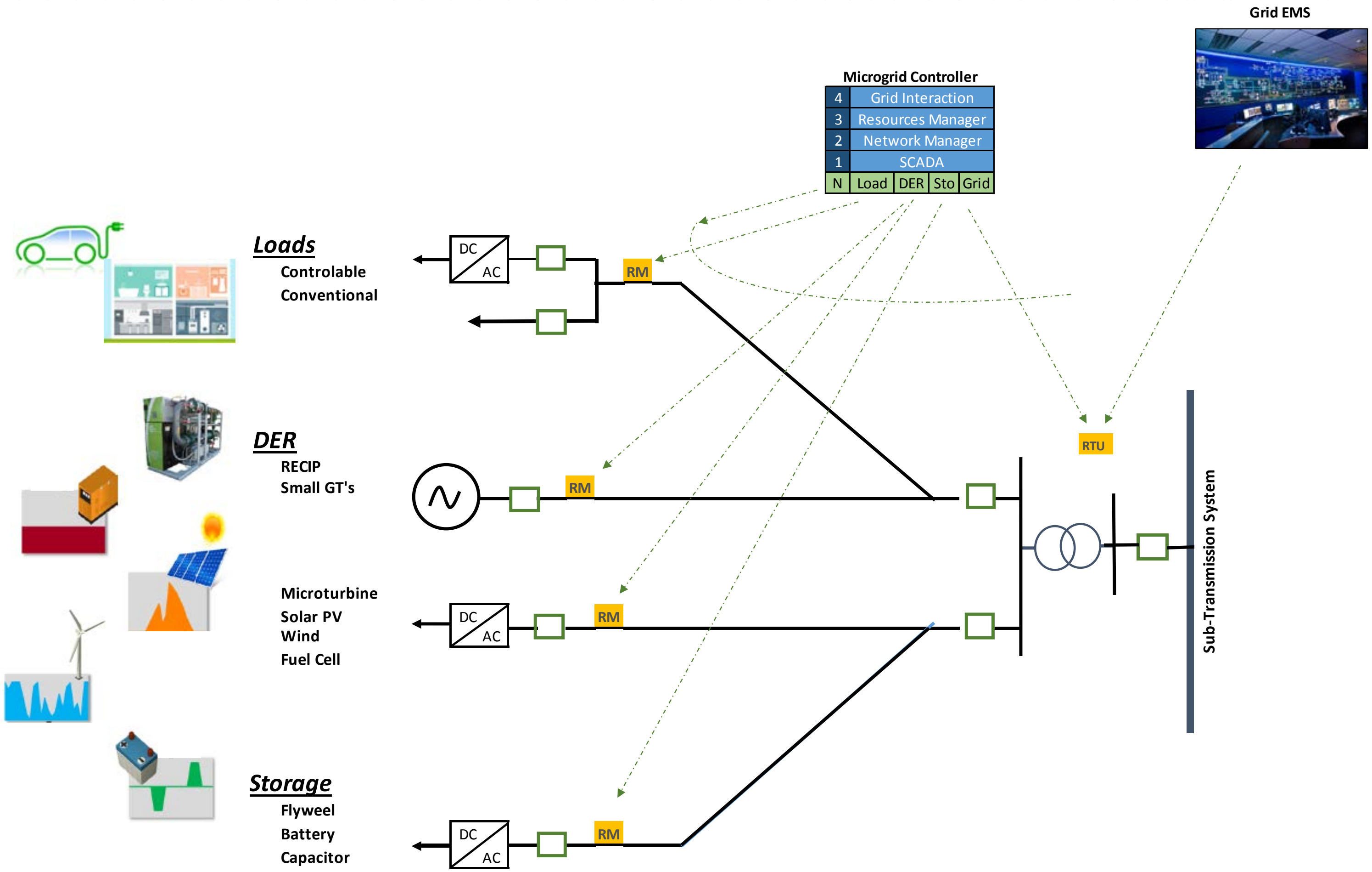
- μ-grids
  - Concept, Operation and Control
  - Economics and Development Timeline
- Energy Sector Transformation
- μ-grids and Regional Grids to Improve Resiliency
- Key Takeaways
- Credits and References

μ-grids Concept

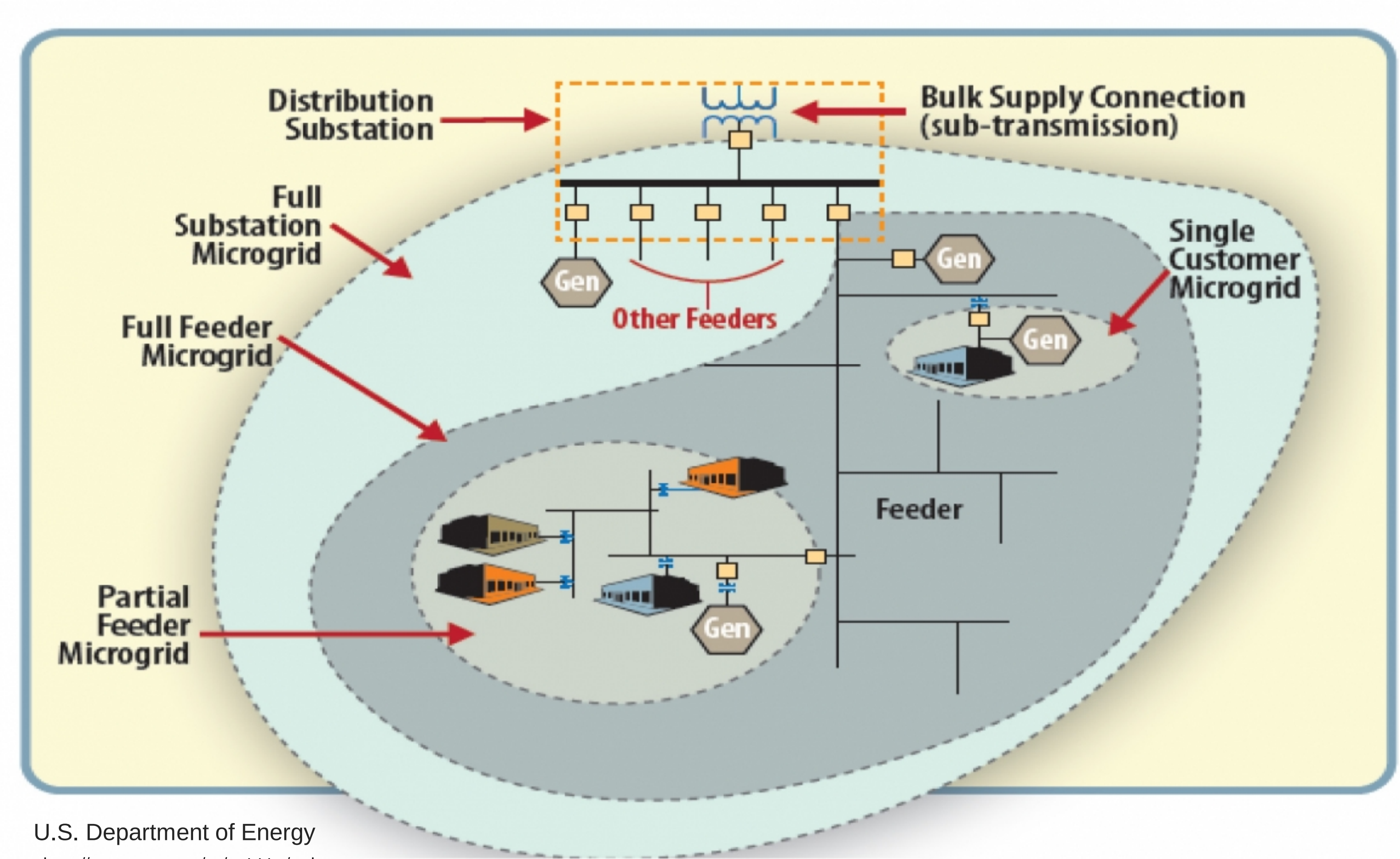
- Comprise LV distribution system with small scale **distributed energy resources** together with **controllable / conventional loads** and **storage devices.**
- Can be operated in a **non-autonomous** way, if interconnected to the main grid, or in an **autonomous** way, if disconnected form the grid.
- **Optimization of resources** is the main difference from a passive grid penetrated by microsources.
- Typical aggregated capacity of a microgrid is in the order of **kW's to low MW's** range.
- Should provide benefits to the overall system performance, if **managed and coordinated efficiently**.

Definition adapted from EU Research Projects [3,4];

μ-grids Concept



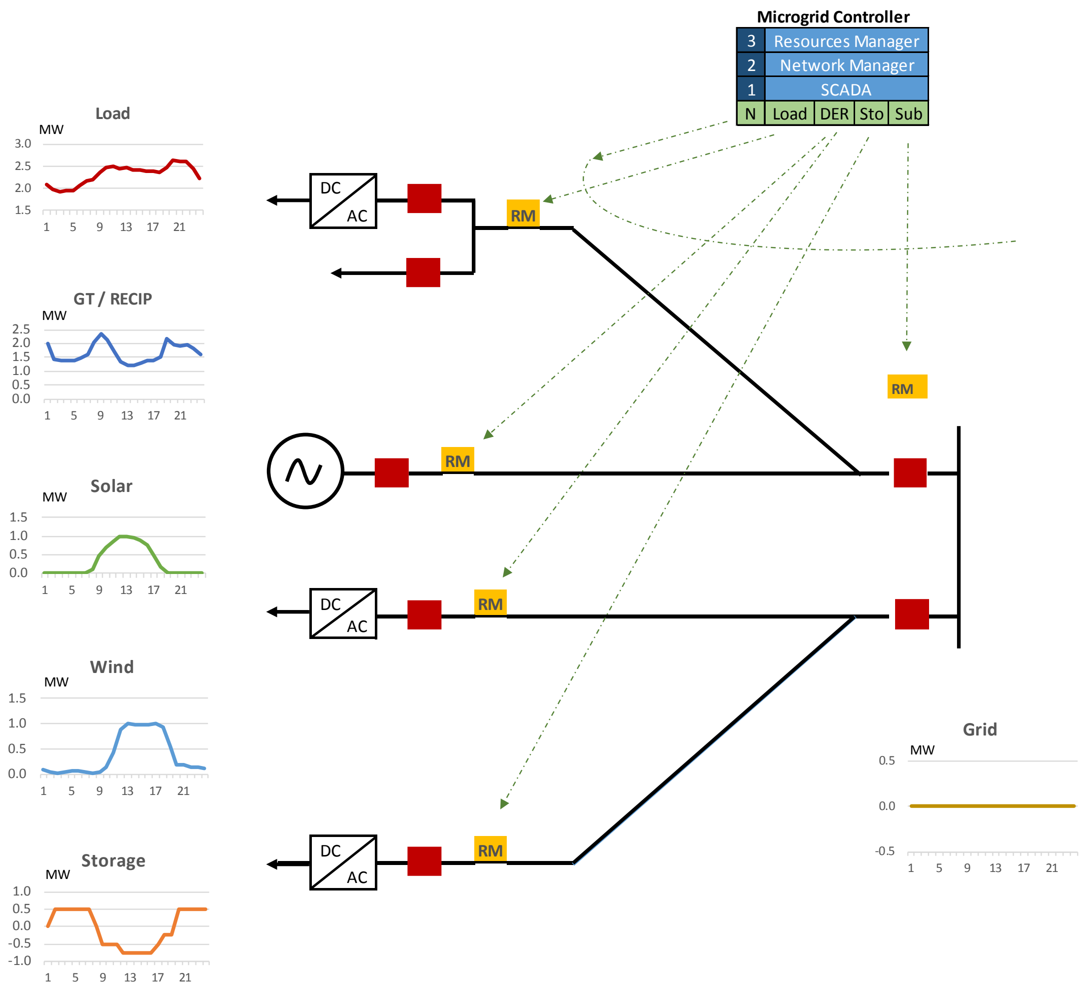
μ-grids Concept



U.S. Department of Energy

https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping

μ-grids Operation - autonomous



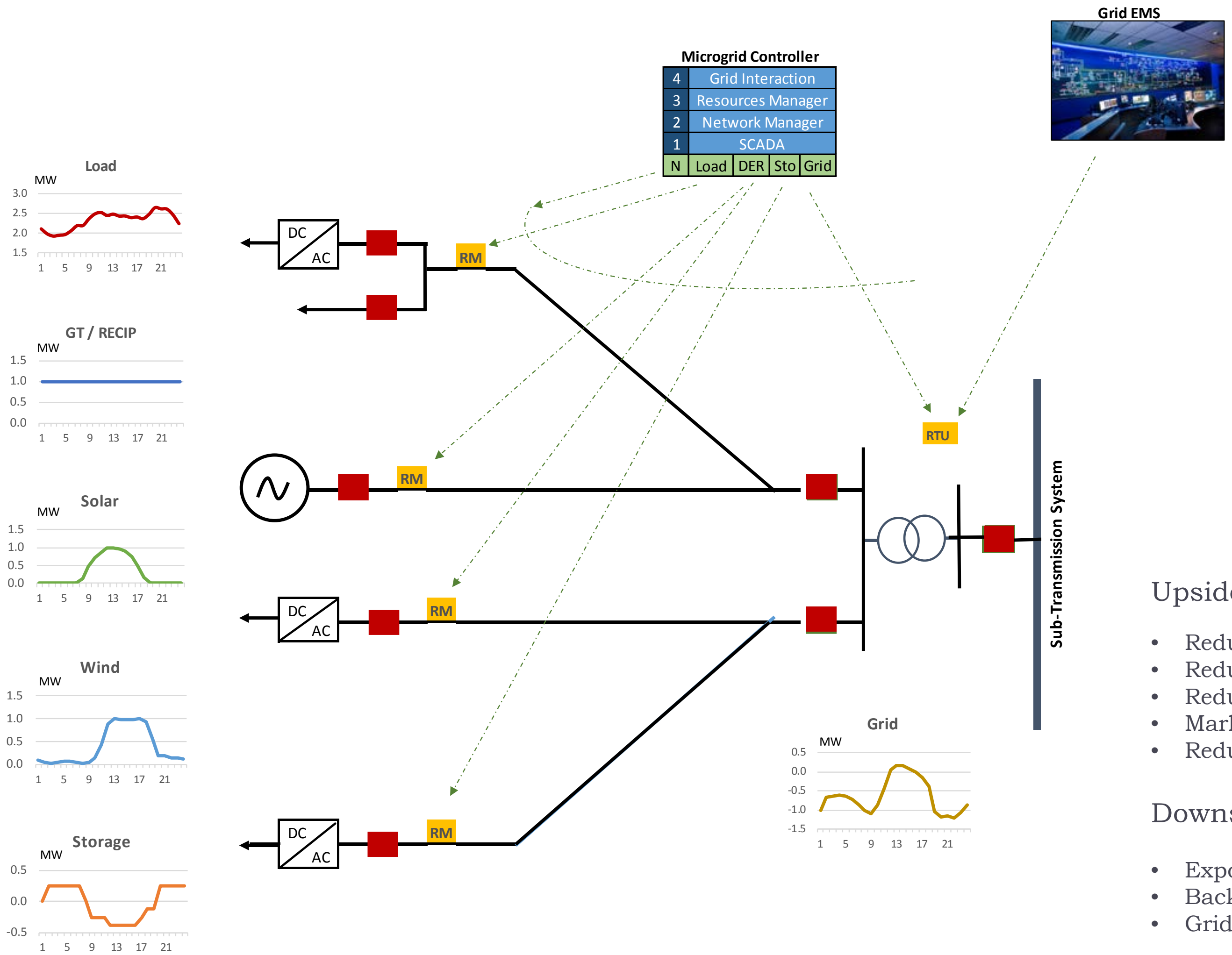
Upside

- Isolated from grid disturbances.
- Increased reliability if properly design.
- No backup power cost.
- No grid services cost.

Downside

- Additional gen capacity for reliability.
- Duty on DER resources.
- Increased storage requirement.
- Operational requirements.
- Reduced optimization opportunities.

μ-grids Operation - interconnected



Upside

- Reduced gen capacity requirement.
- Reduced storage requirements.
- Reduced duty on DER.
- Market participation opportunities.
- Reduced operational requirements.

Downside

- Exposed to grid disturbances.
- Backup power cost.
- Grid services cost.

μ-grids Control

Grid Interface
Remote Terminal Unit

- Operating Mode – Islanded / Autonomous
- Market / System Dispatch Participation
- Upstream Coordination – Normal / Emergency

Resource Manager
Microgrid Controller

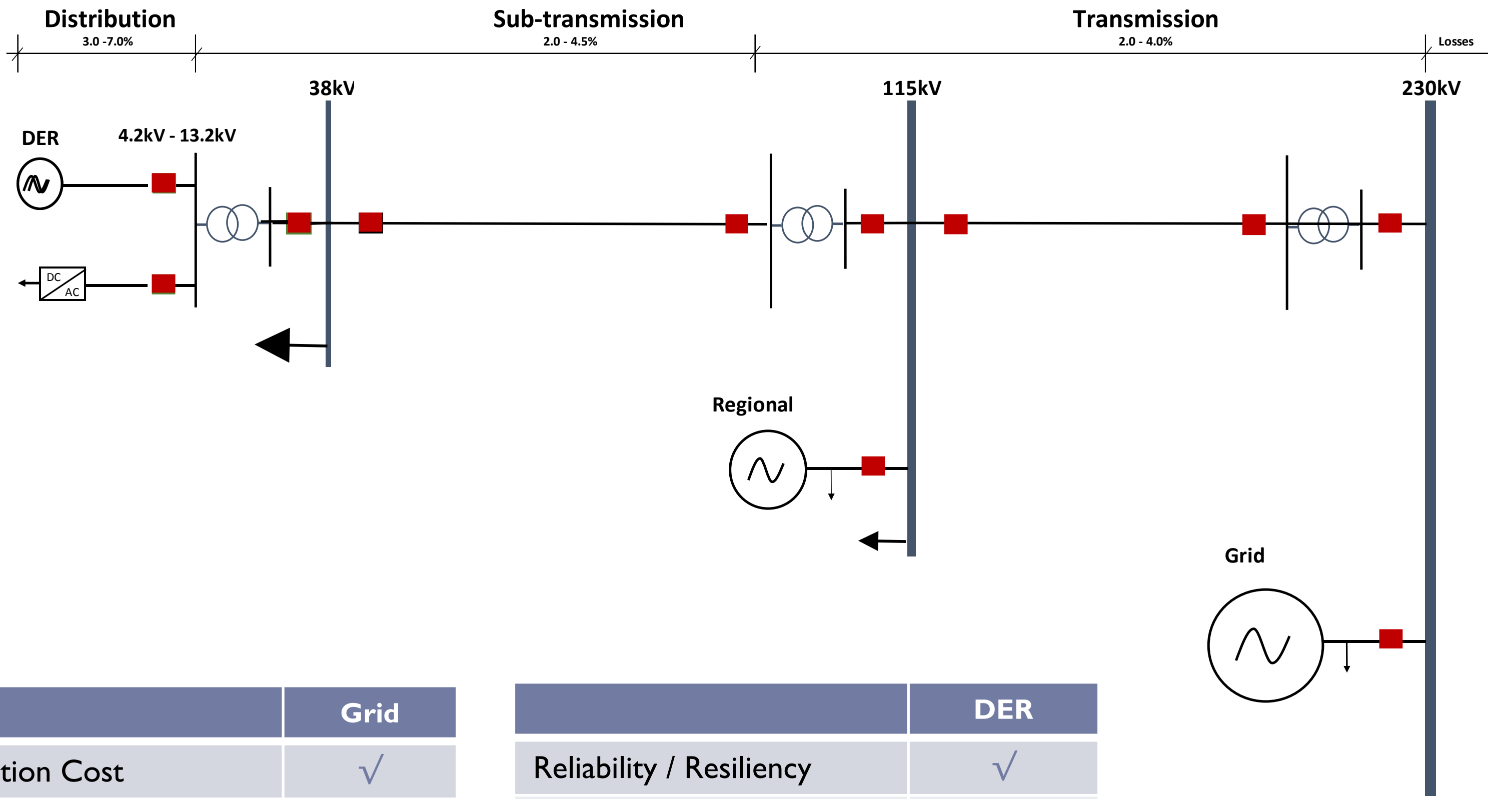
- Secondary Frequency / Voltage Control
- Load Management / Shedding
- Resources Commitment & Dispatch
- Blackstart

Local Control & Protection
Relay, PLC, Remote Meter

- Protection
- Primary Frequency / Voltage Control
- Storage Management

- Challenges;
  - Protection coordination for wide range of operating regimes and short circuit availability.
  - Resources availability forecasting and modelling for effective DER optimization.
  - Properly designed and robust communication assisted and adaptive protection schemes.
  - Requirements and models for ancillary services utilization / supply (ex. ramp control).

μ-grids Economics



	Grid
Production Cost	√
Grid Services	√
Backup Power Cost	√
Operation & Control Cost	√

	DER
Reliability / Resiliency	√
Local Socio-economics	√
T&D Losses	√
T&D CAPEX	√

Assessment from PR Electric System Perspective.

µ-grids Development Timeline

2010 - 2015
Early Stage

- Cost Reduction of RES and CHP
- Aging Infrastructure
- Electricity cost fluctuations
- Environmental awareness

2015 - 2020
Boom of DER

- Regulatory Framework Development
- Locational value of DER awareness
- Flexible Loads enabled DSM
- Resiliency and reliability awareness

2020 - 2025
Local Markets

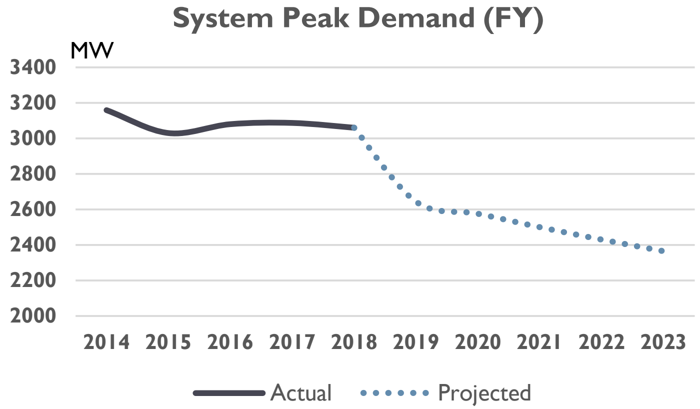
- RES and Storage Cost Reduction Continue
- Smart Metering Solutions Popularized
- Reduced Control & Communications Cost
- Consumers Active Participation in Supply Chain

2025 - 2030
Fully Integrated

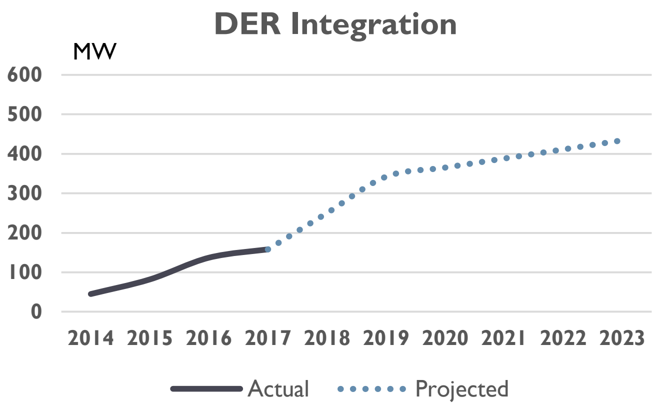
Adapted from Microgrid Architecture & Control [1]

Energy Sector Transformation

Total System Generation	PREPA & IPP's 6,058MW total, 246 Grid Scale Renewable 78% oil fired, 450MW largest unit
Regional Generation	22 units – 21MW frame 5 & 55MW FT8 GT's 21 units – 100MW small hydros
Distributed Generation	Solar PV, Wind, RECIP, Industrial GT's 158 MW Net Metering (registered Dec 2017) ??? MW Behind the meter generation.
Microgrids	**DER + Loads + Storage + Controller**



PREPA Fiscal Plan – Load Factor assumed at 75%.

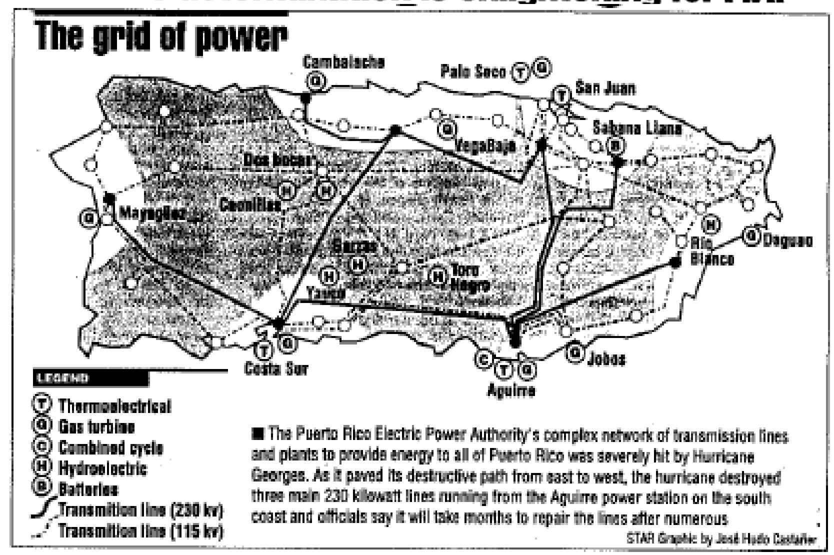


DER Capacity Factor Assumed at 30%.

μ-grids and Regional Grids to Improve Resiliency

- Decentralized Generation with Blackstart Capability;
  - Key in system restoration strategy after Hurricanes.
  - Part of PREPA electric system planning, design and operation since decades.
  - Islanded operation during restoration is the correct solution when appropriate resources are available.

- GEORGES vs MARIA System Restoration;
  - Hurricane intensity and translation velocity.
  - Maintenance status of Generating fleet.
  - Emergency Communications Systems.
  - Maintenance status of T&D.
  - Availability of qualified human resources.


LOCAL NEWS

PREPA's determination is enlightening for P.R.

The grid of power

■ The Puerto Rico Electric Power Authority's complex network of transmission lines and plants to provide energy to all of Puerto Rico was severely hit by Hurricane Georges. As it paved its destructive path from east to west, the hurricane destroyed three main 230 kilowatt lines running from the Aguirre power station on the south coast and officials say it will take months to repair the lines after numerous

STAR Graphic by José Hydo Castañer

Caribbean Business – Sunday September 27, 1998.

Key Takeaways

- μ-grids will play an important role of the Puerto Rico Electric System over the next decade. Service reliability and resiliency as a main driver on short term.
- RES and Storage price decline as well as CHP solutions will become an important enabler factor over the next ten years.
- Protection and control solutions as well as optimization tools continue on development stage.
- Currently μ-grids are, in most cases, more expensive than technologically updated and efficiently operated centralized generation.
- Energy sector should be prepared with legal and operational framework for;
  - Off-grid energy production cost and reliability reach parity with grid energy.
  - Battery electric vehicles cost and performance reach parity with conventional vehicles.
  - Cost of distributed generation reach parity with grid production and transmission cost.

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