NATIONAL RENEWABLE ENERGY LABORATORY

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IGP: Modeling Tools and Evolving Technology Trends

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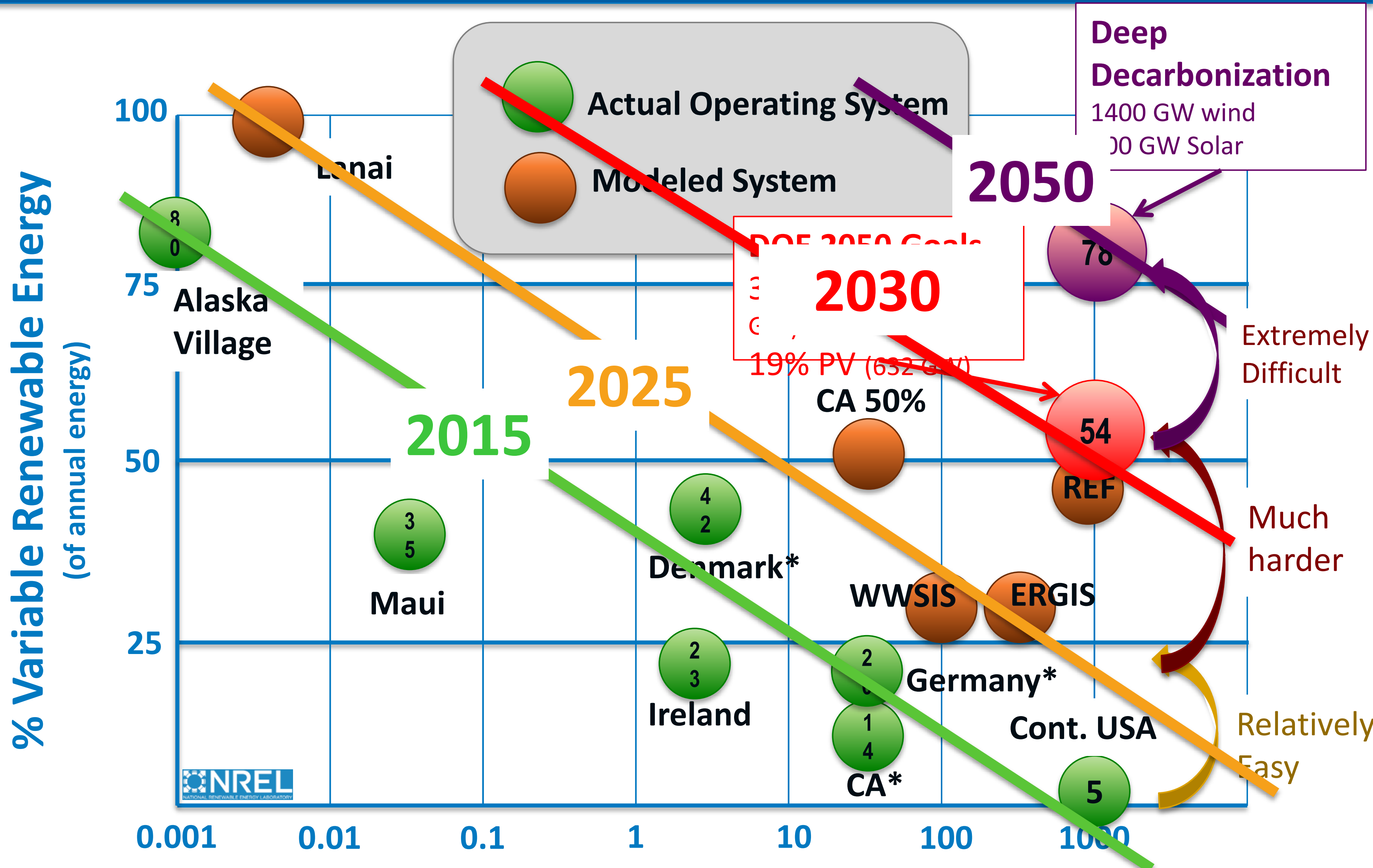
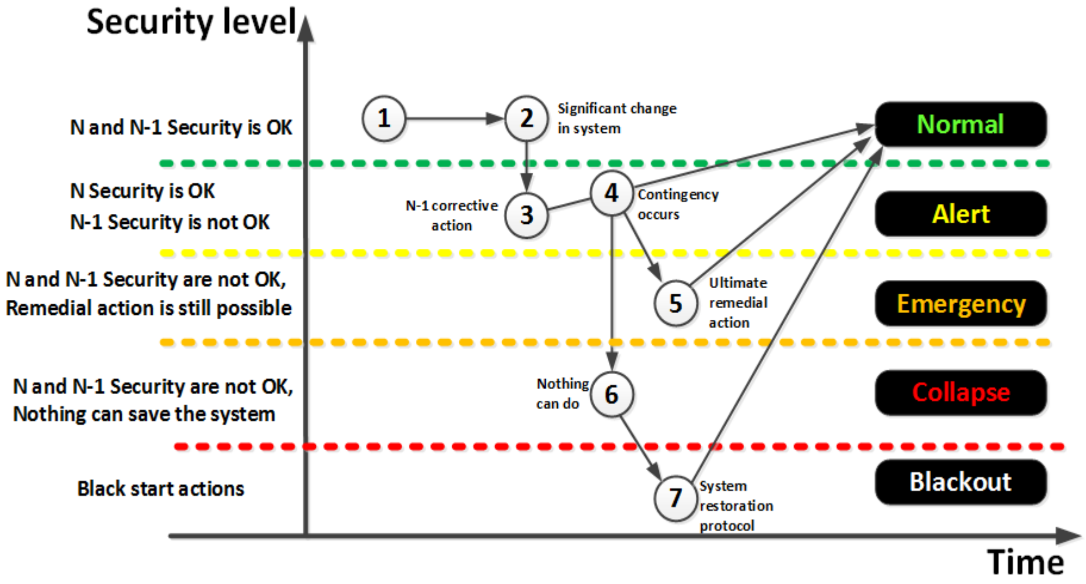
Transforming the grid at a pace and scale that matter



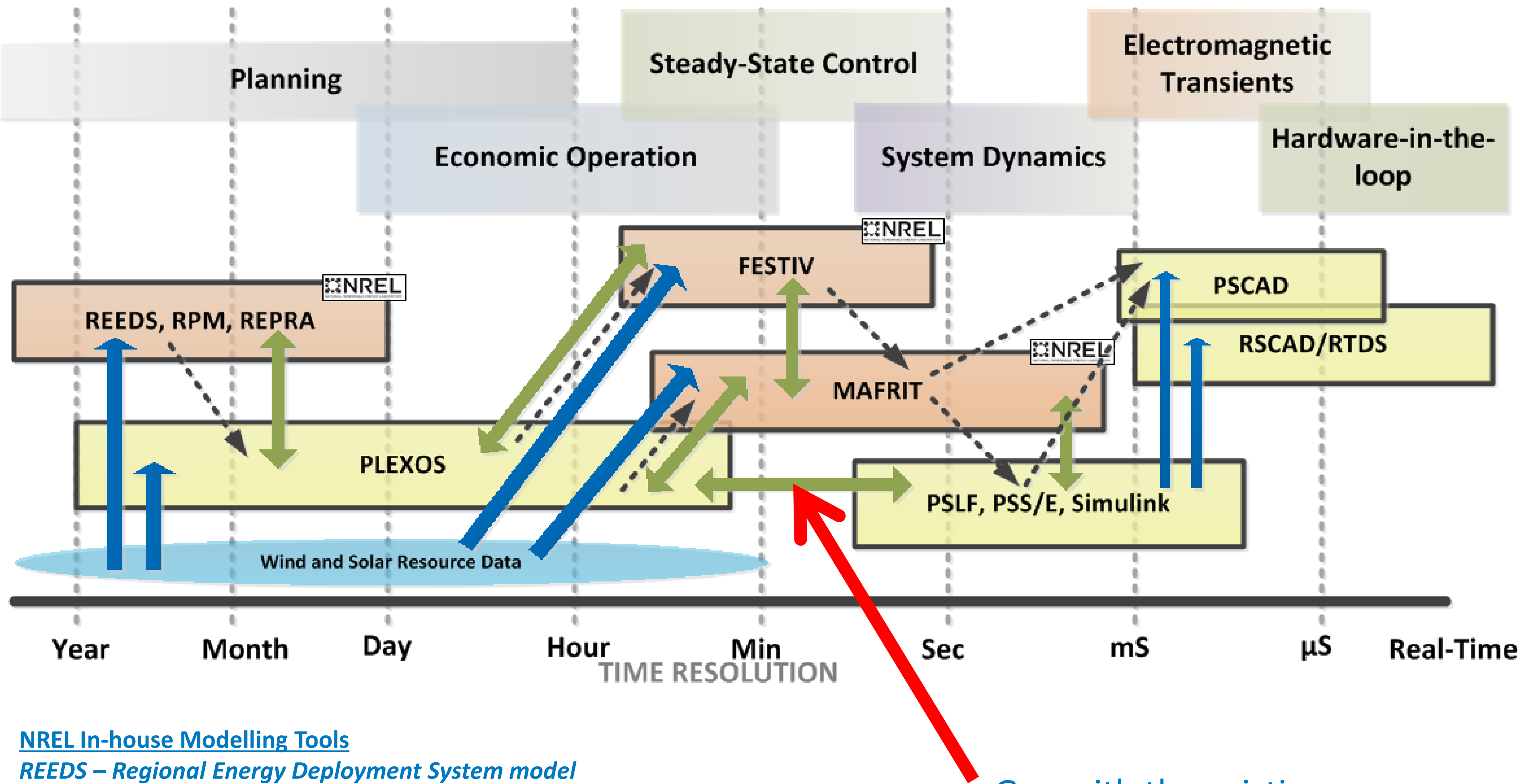
* Part of a larger synchronous AC power system

IGP for Secure and Reliable Island Grids

- Need in methodological framework using multi-model approach to assess and evaluate options for enhancing system security and reducing associated risks at different time frames
- Island grids are exposed to various types of vulnerabilities
- Island power system security must be defined as multi-dimensional system property optimized to cope with wide range of potential risks:
  - Resilience
  - Economic Efficiency
  - Low or zero emissions
  - Adequacy
  - Stability
  - Robustness



Software Tools for Grid Integration used by NREL



NREL In-house Modelling Tools

REEDS – Regional Energy Deployment System model
RPM – Resource Planning Model Tool
REPRA - Renewable Energy Probabilistic Resource Assessment tool
FESTIV – Flexible Energy Scheduling Tool for Integrating Renewables
MAFRIT – Multi-area Frequency Response Integration Tool

Gap with the existing commercial software tools

ReEDS Tool

- Regional Energy Deployment System (ReEDS) model to optimize and visualize the build-out of electricity generation and transmission systems
- Identifies cost-optimal mix of technologies based on:
  - Regional demand requirements
  - Grid reliability requirements
  - Resource and policy constraints

Renewable Electricity Futures Study

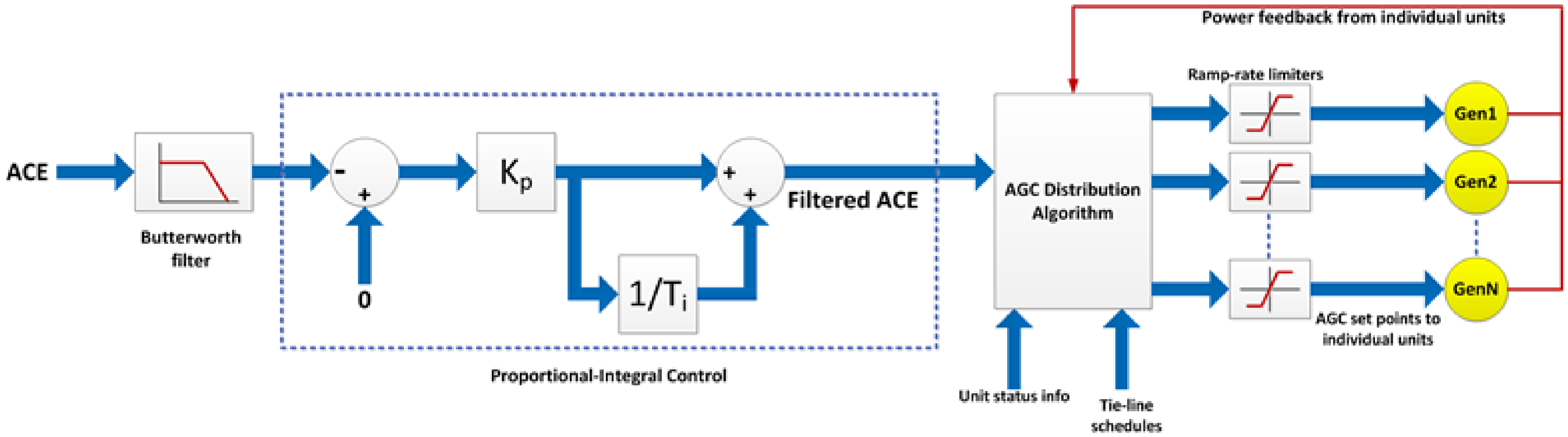
SunShot Vision Study

REPRA and RPM Tools

- Renewable Energy Probabilistic Resource Adequacy (REPRA) tool
  - Helps understand how different generation types can contribute to the resource adequacy from a reliability point of view
- Resource Planning Model (RPM) – capacity expansion model designed for a regional power system
  - Optimization model to find the least-cost investment and dispatch solution over a 20-year planning horizon
  - Dispatch modeling within RPM is conducted using hourly time-steps sampled throughout a year, and the model considers energy balance, reserves, and many generator constraints

Enhancing PLEXOS Production Cost Model

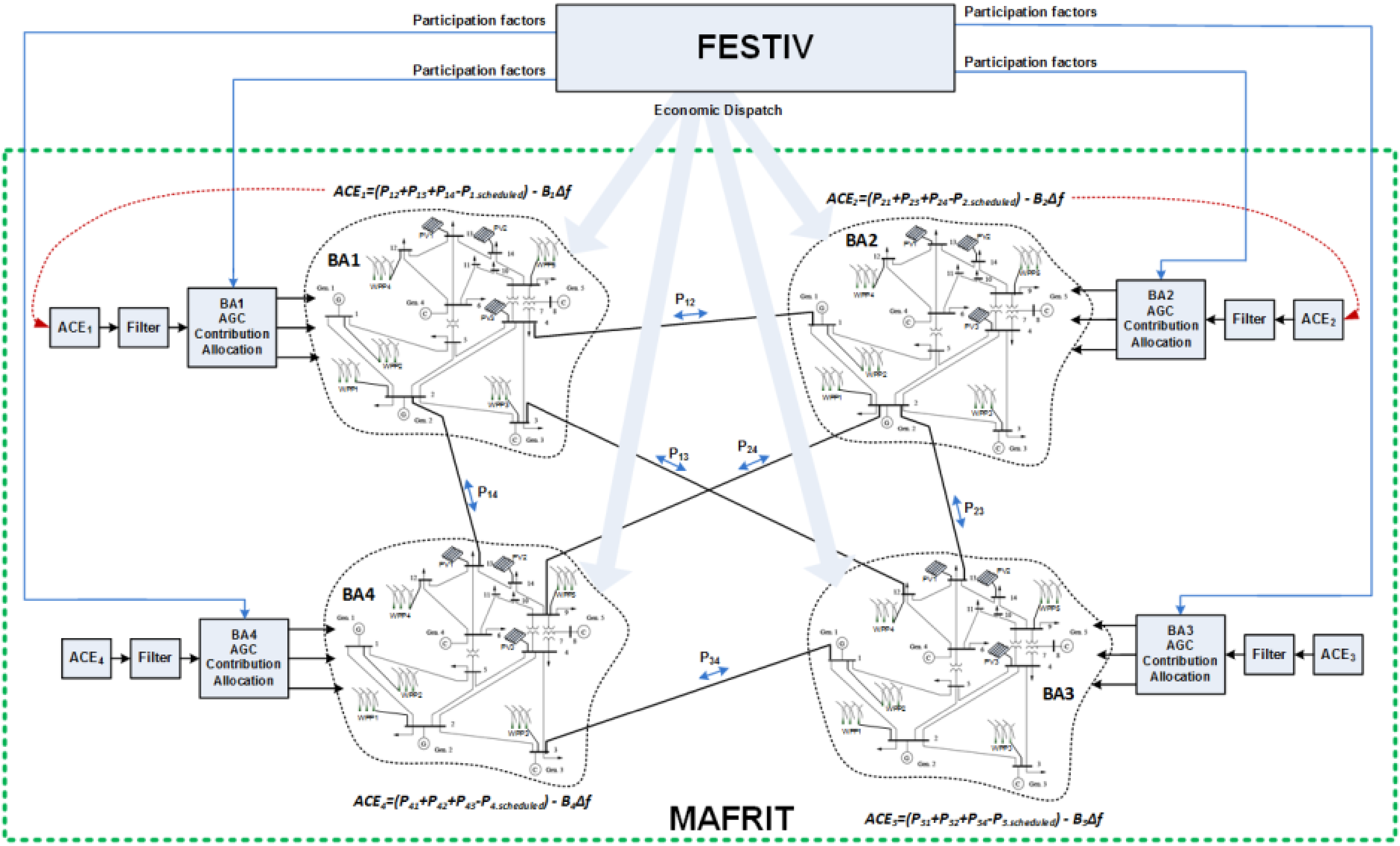
- NREL works with Energy Exemplar to add the new capabilities to model system operation at a 1 sec resolution and then build on this capability to provide AGC and estimates of NERC CPC metrics
- Use cases under development:
  - Quantifying the operational benefit of flexible energy storage
  - Refined market designs with improved reliability model



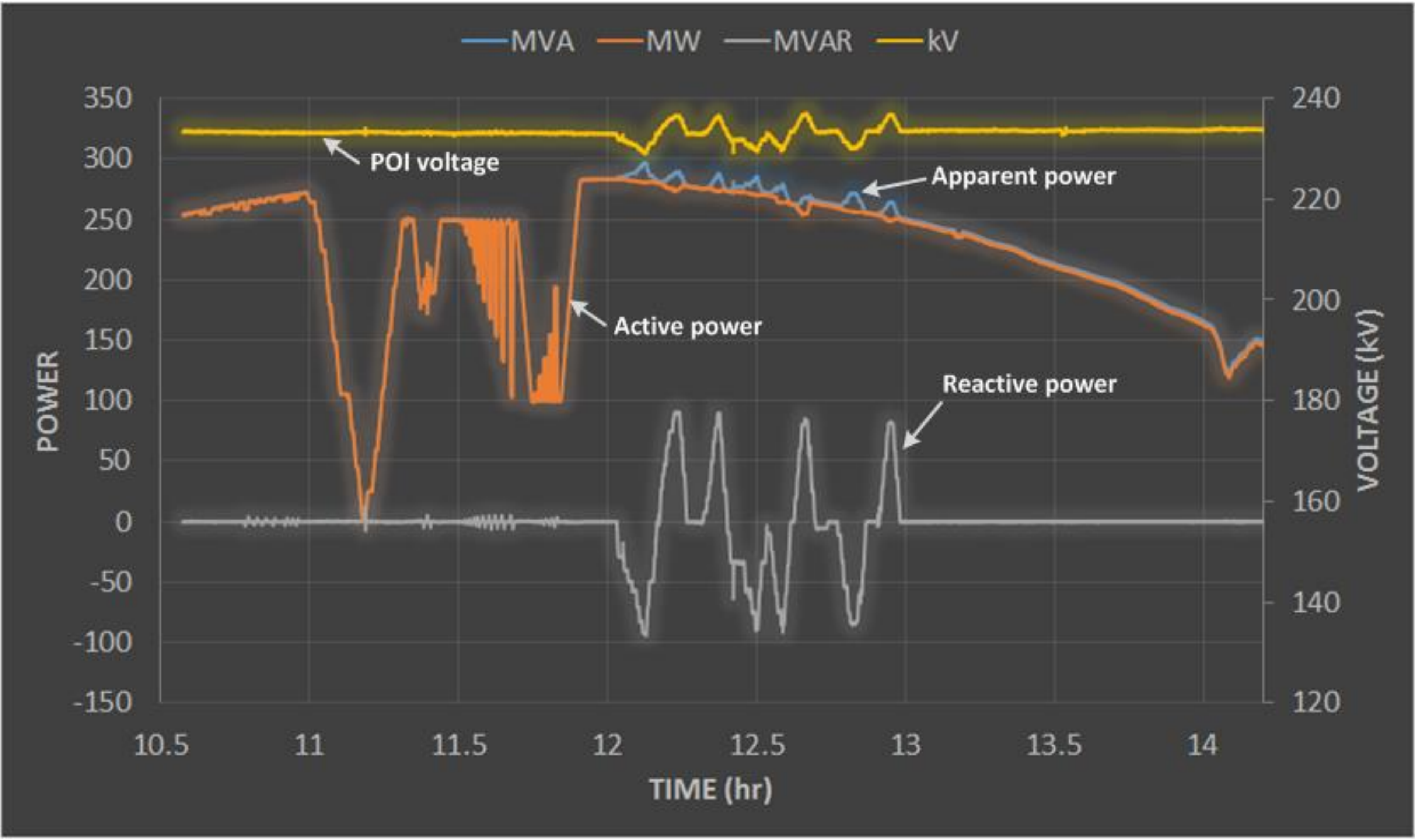
FESTIV and MAFRIT

- Flexible Energy Scheduling Tool for Integrating Variable Generation **(FESTIV)** tool
  - Evaluates impacts of variability and uncertainty on power system operations (multiple-timescale, interconnected simulation)
  - Produces both economic and reliability metrics
  - Evaluates trade-offs in economic and reliability benefits, and incentive structures
- Multi-Area Frequency Response Integration Tool **(MAFRIT)** allows integrating primary frequency response with AGC
  - Simulates the power system dynamic response in full time spectrum with variable time steps, from millisecond to minutes to hours and days
  - Simulate both normal and event conditions, can represent real power system operations and evaluate the primary and secondary reserves adequacy
  - Can be used for a single-area island system

Linking MAFRIT and FESTIV



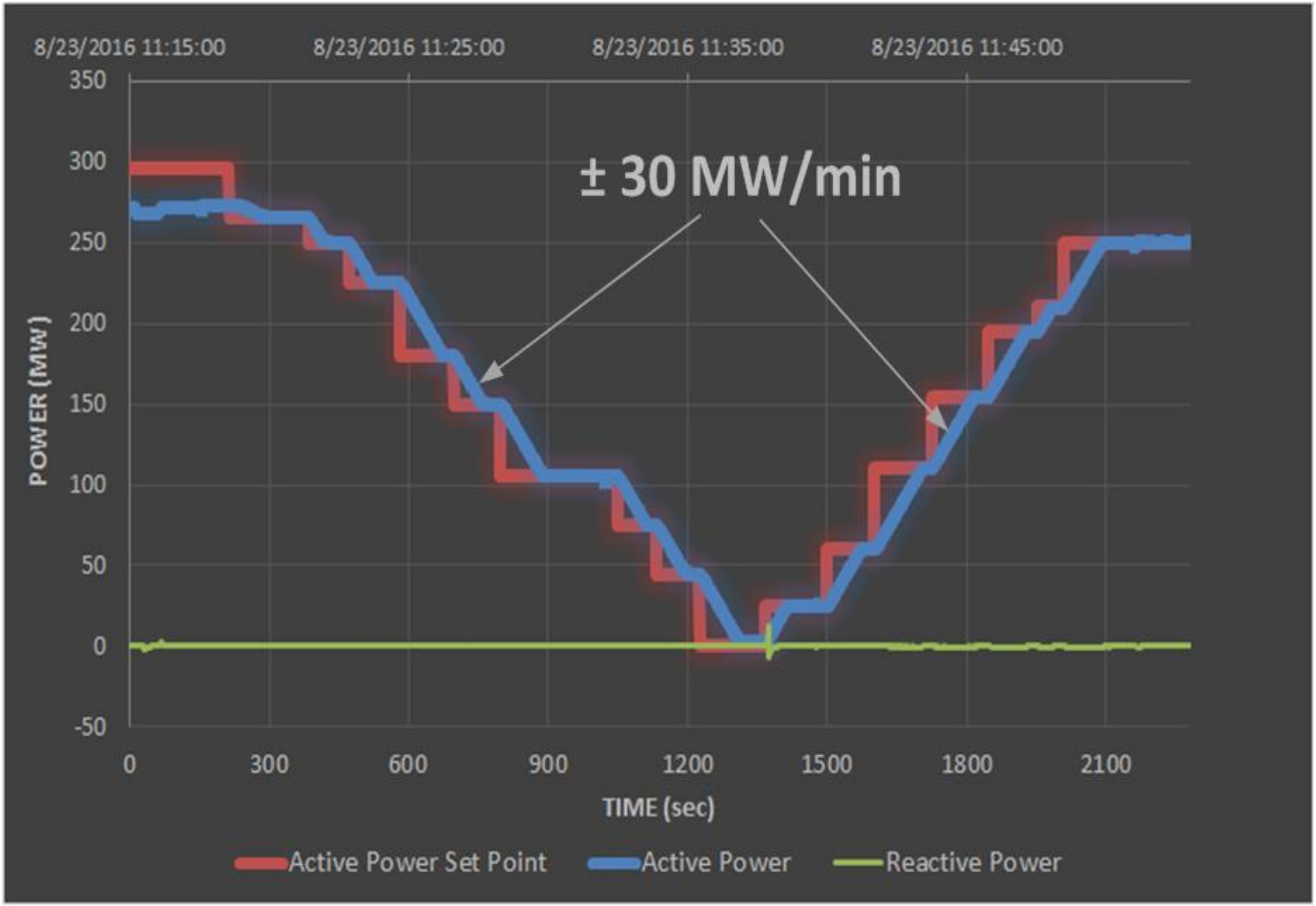
Testing 300-MW PV Plant for Grid Services



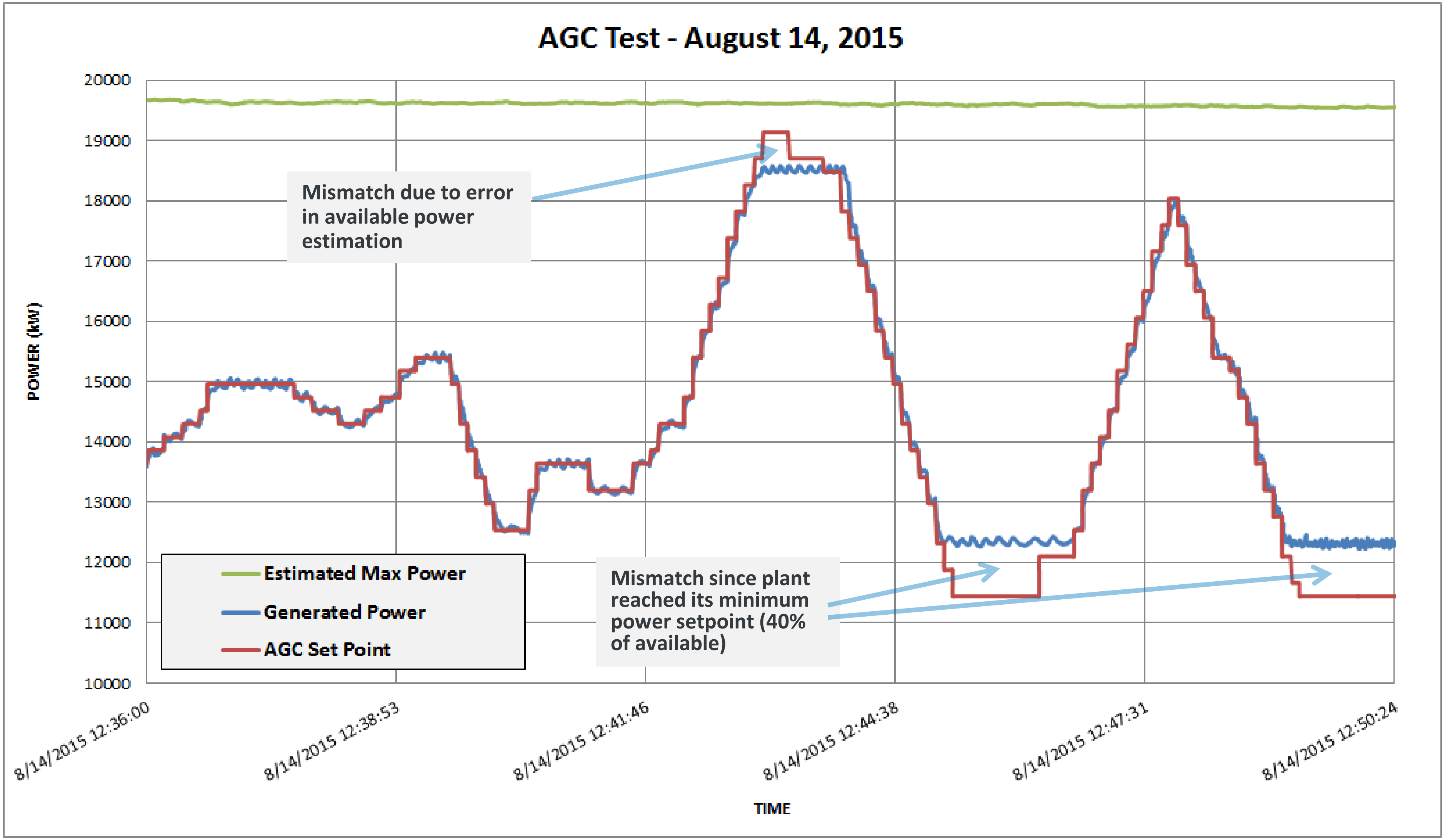
Snapshot of PREPA AGC Display #4

No conventional unit is selected for AGC, AES Ilumina is the only active unit

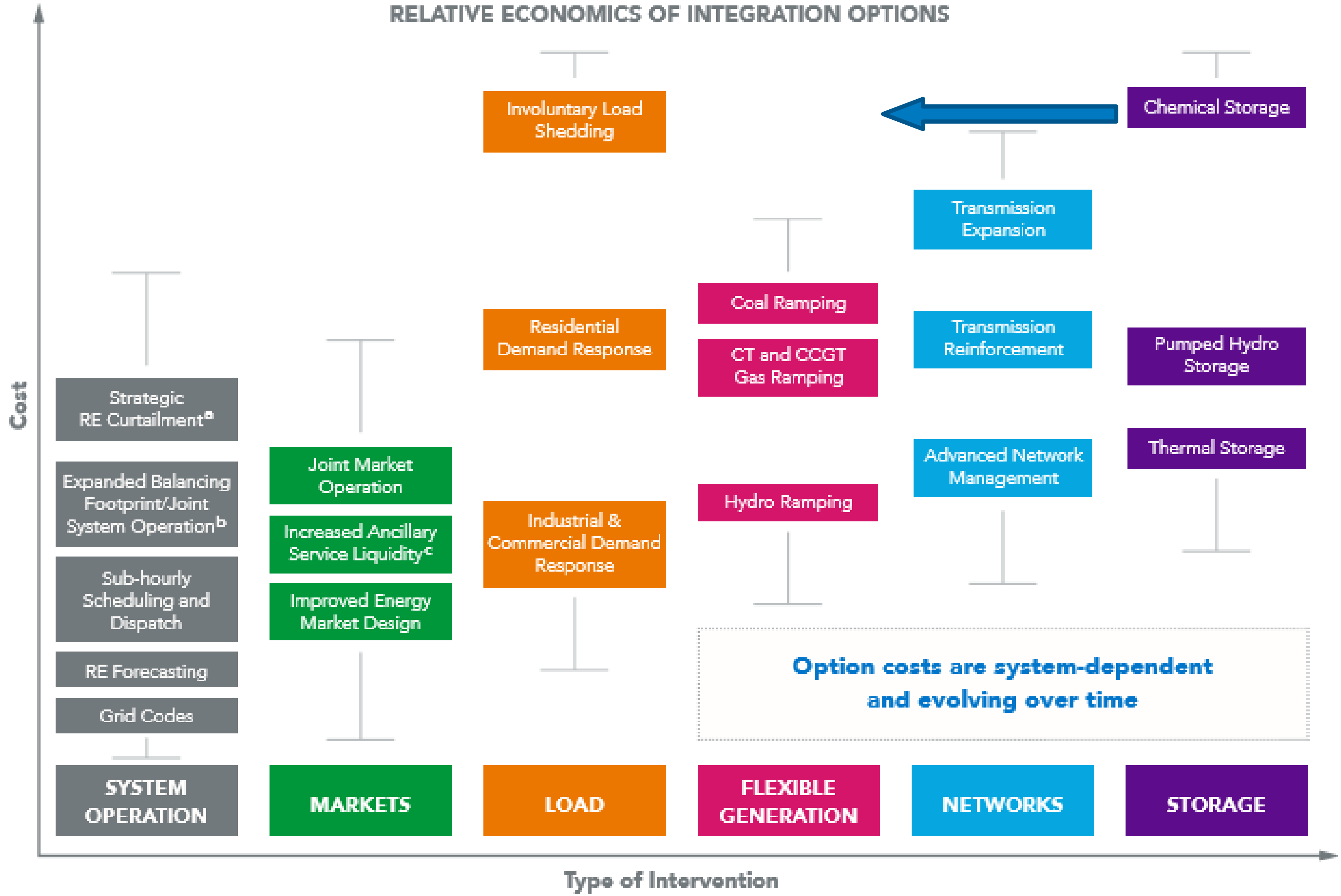
Active Power Curtailment Test



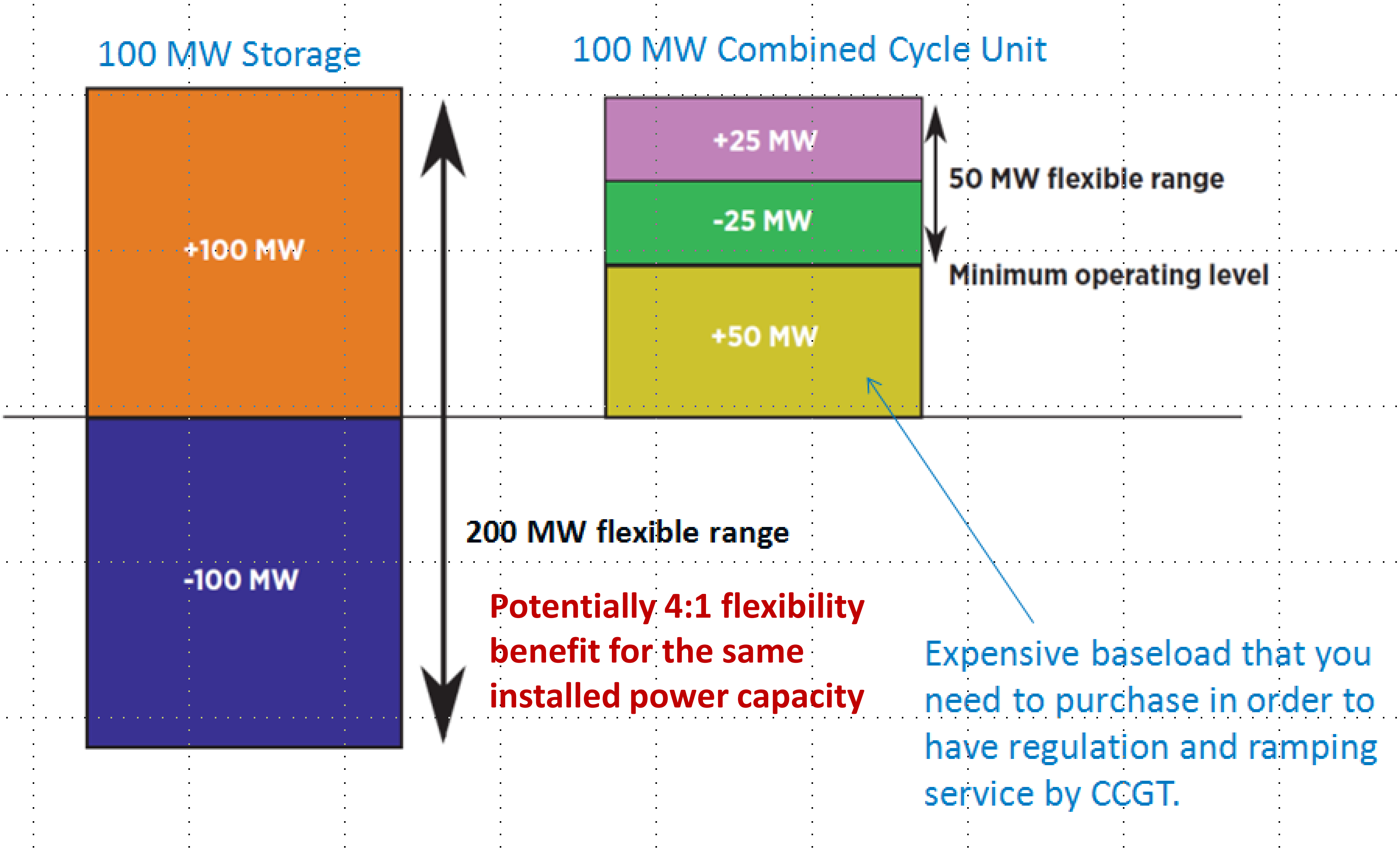
Plant AGC Performance



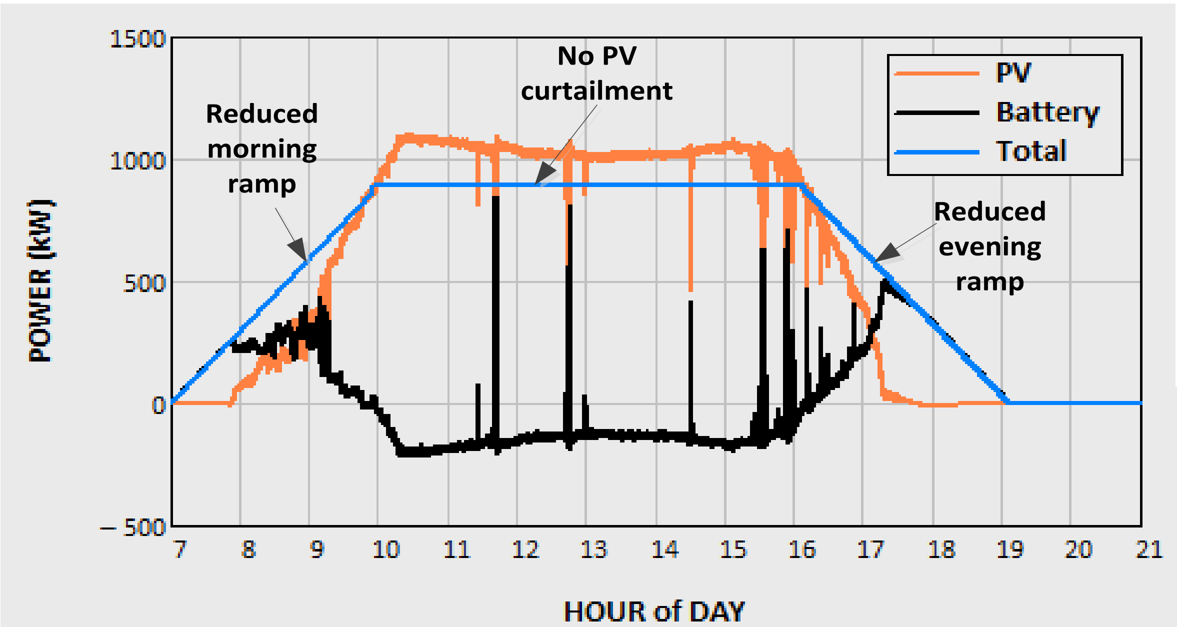
Changing Flexibility Resources Landscape

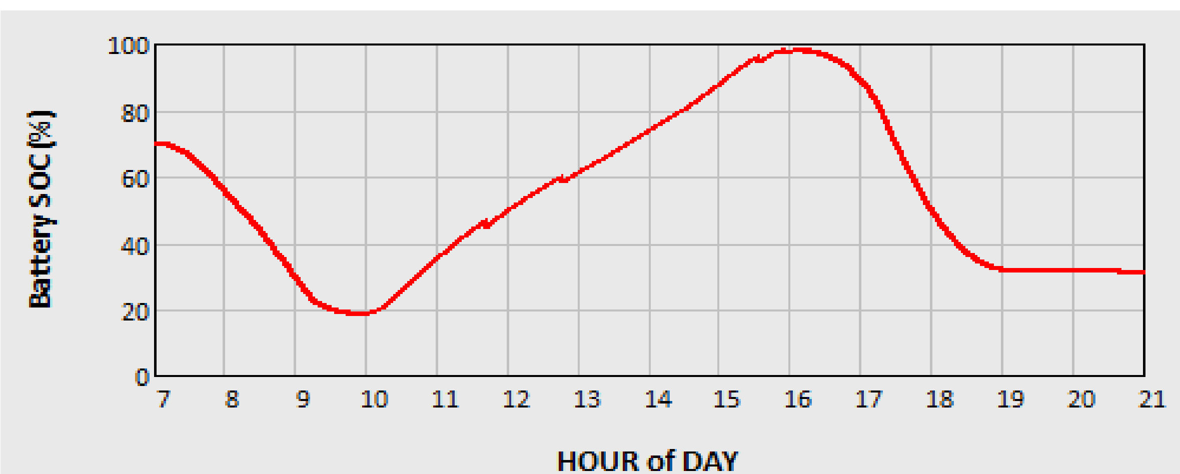


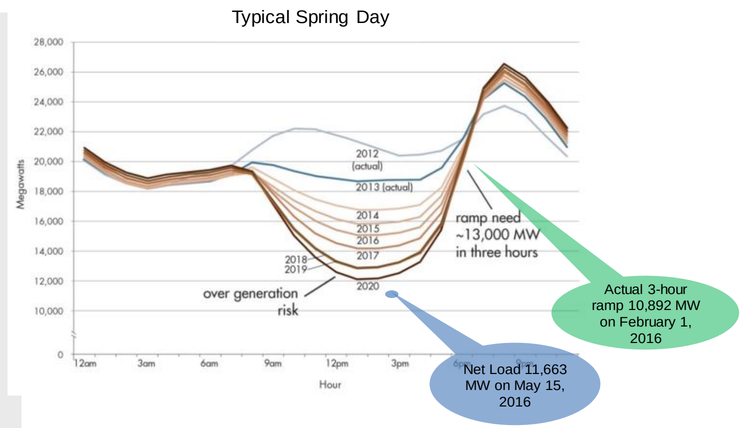
Energy Storage vs. Combined Cycle for Ancillary Services



BESS for PV Curtailment Reduction and Ramp Control

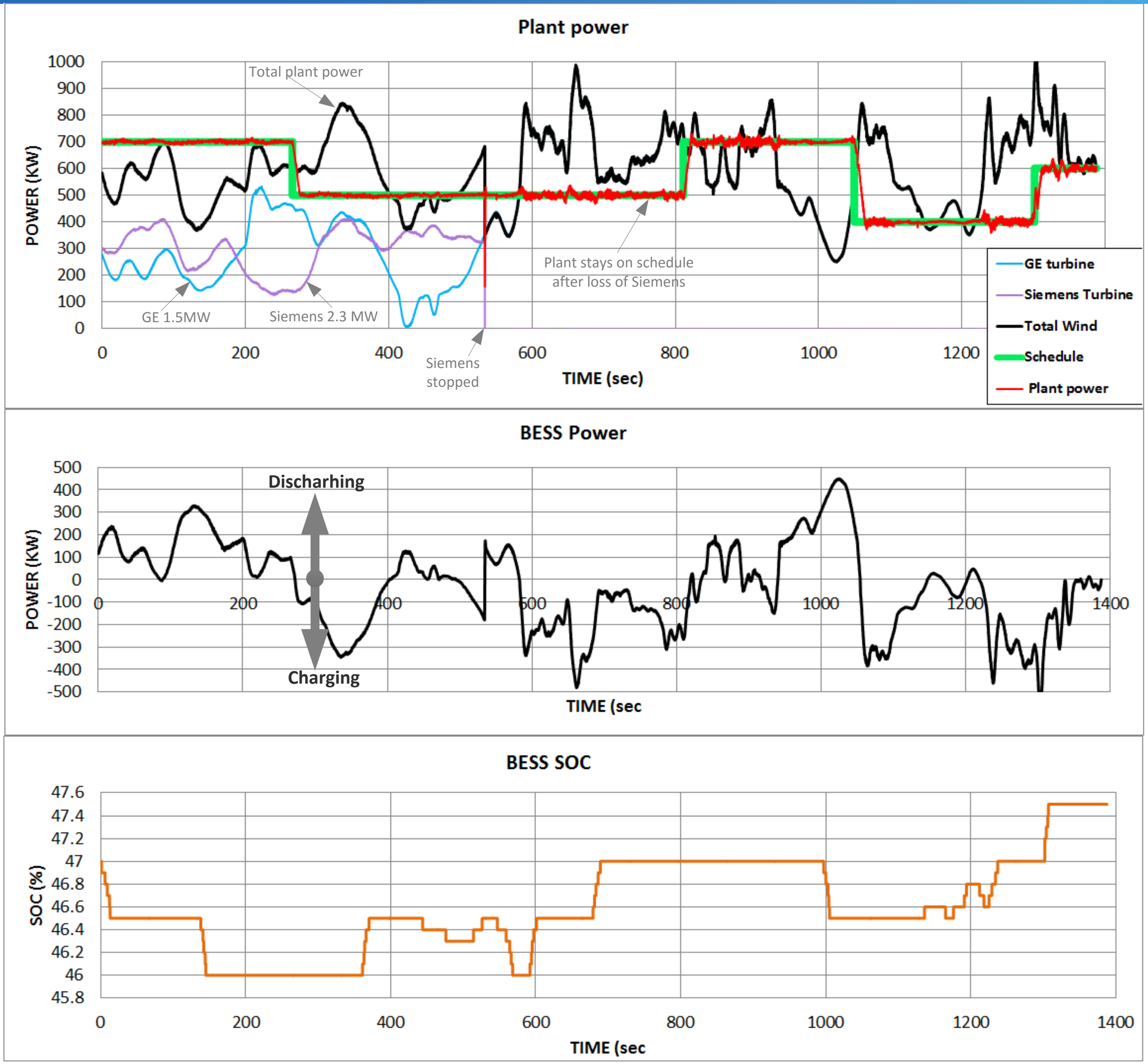






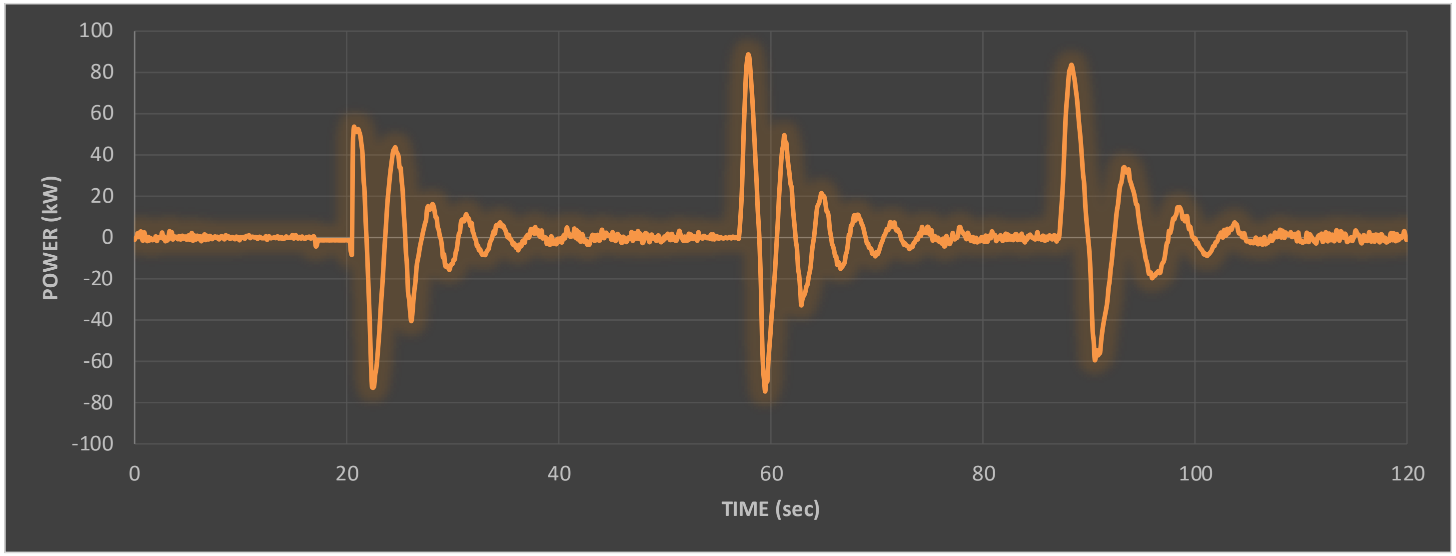
- Reduce PV curtailment
- Limit morning and evening net load ramps
- PV as a dispatchable source and provider of essential reliability services

Dispatchable Hybrid Wind-BESS Plant Demonstration



BESS Providing POD Response

Demonstration of Power Oscillations Damping control by BESS



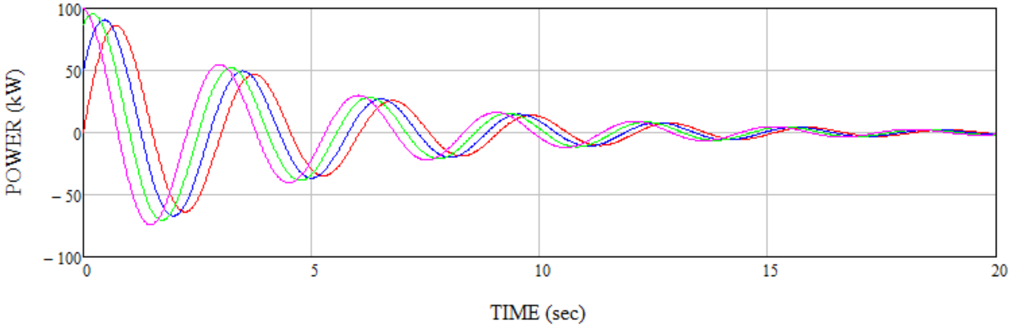
Magnitude of POD response

Frequency of oscillations

$$P(t) = P_m e^{-\frac{t}{T}} \sin(2\pi f t + \varphi)$$

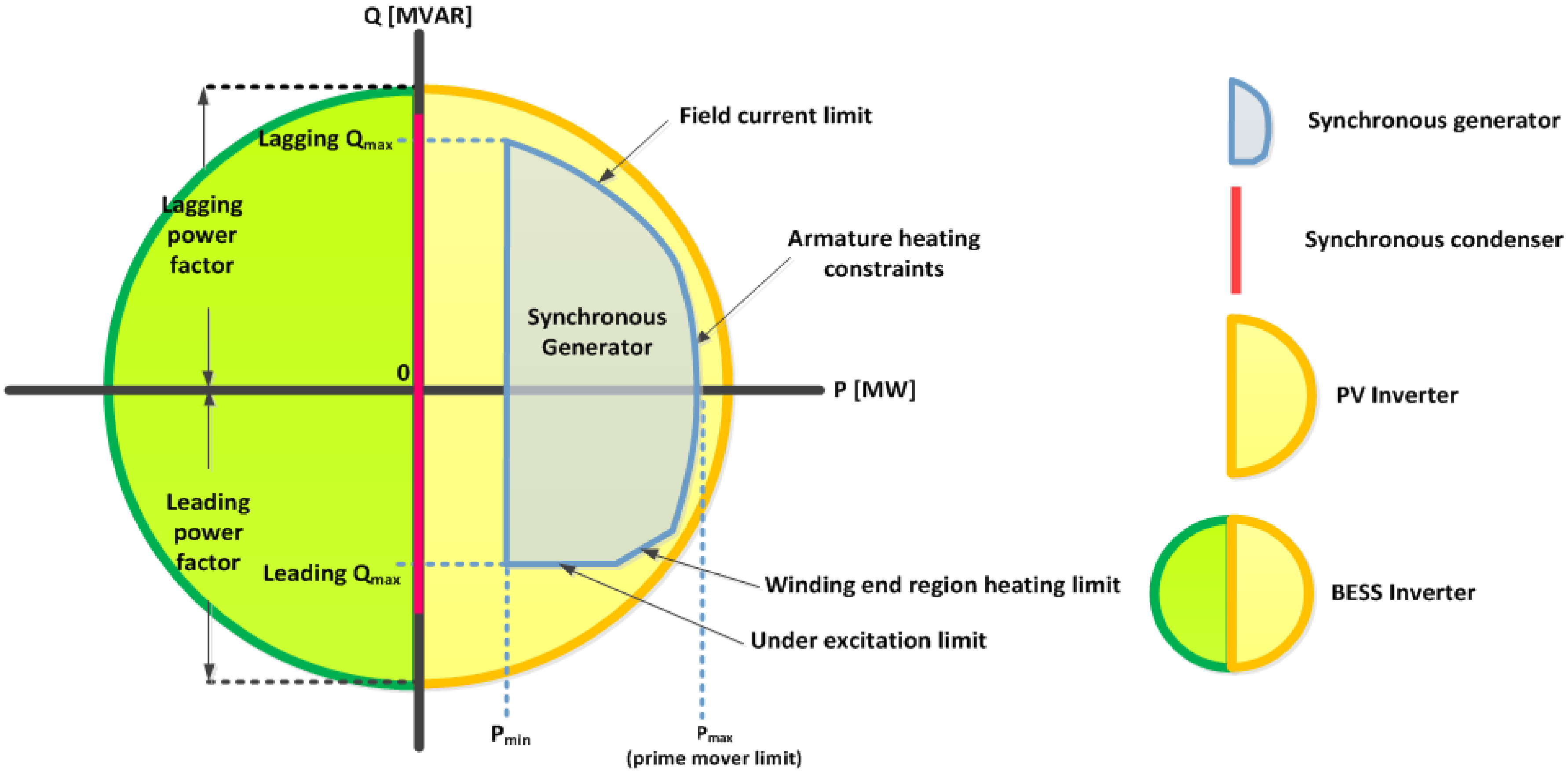
Decay time

Phase angle of oscillations



Important to trigger with correct phase angle (right time) and frequency!

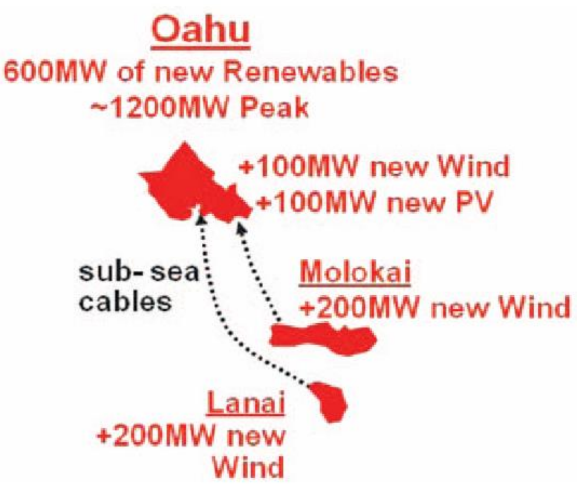
Reactive Power and Voltage Control Services



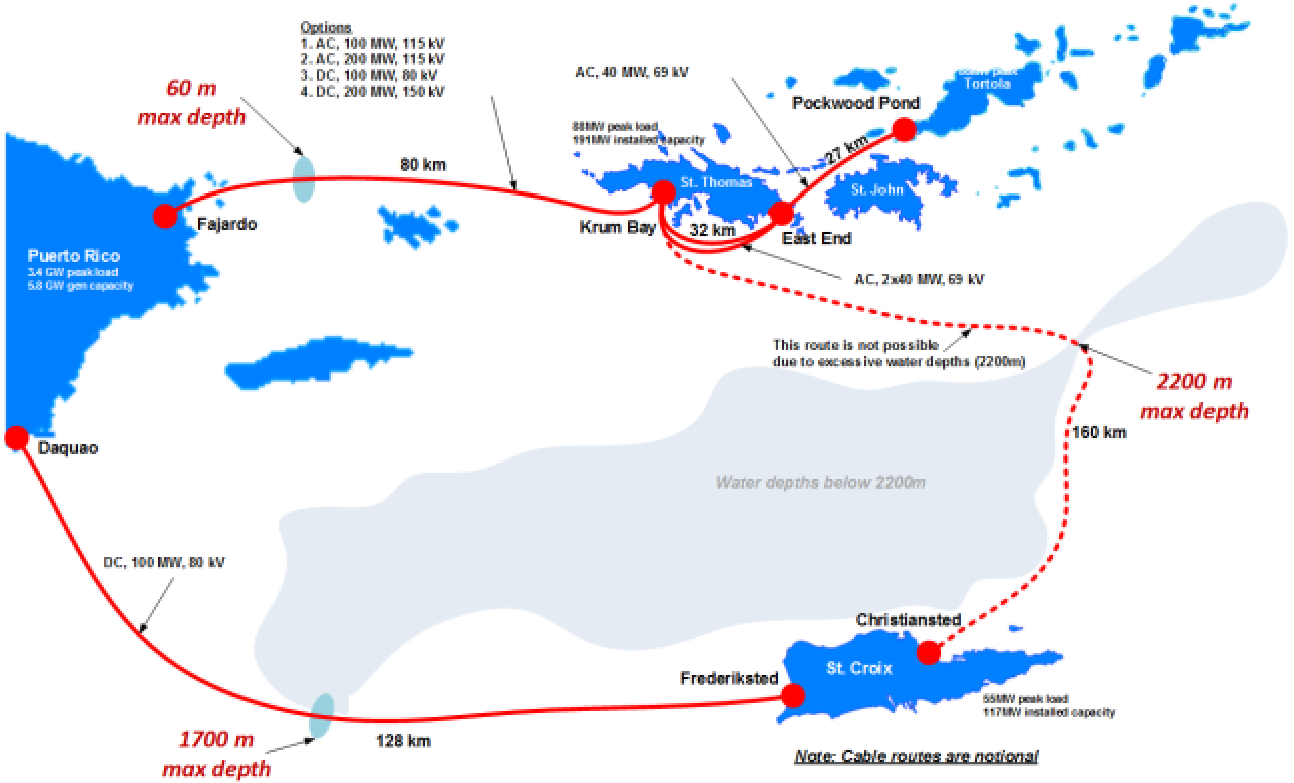
- 2-quadrant P-Q characteristic for wind and PV inverters
- Full 4-quadrant P-Q operation with energy storage

Submarine Inter-island Power Transmission

Oahu Big Wind Study



Puerto Rico – USVI – BVI Study



Thank you!

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