



## IGP: Modeling Tools and Evolving Technology Trends

Vahan Gevorgian

Chief engineer for Grid Integration

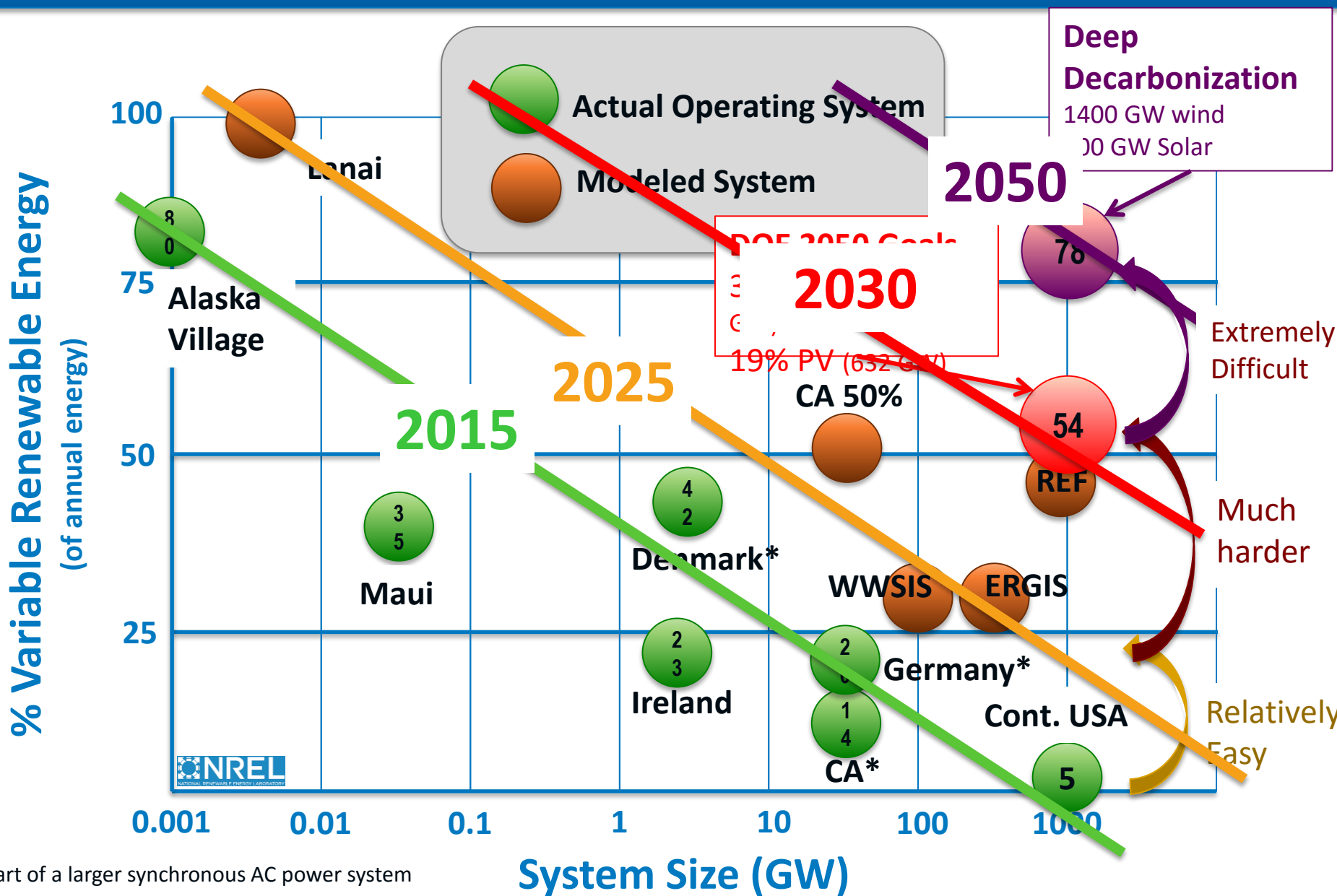
[vahan.gevorgian@nrel.gov](mailto:vahan.gevorgian@nrel.gov)

2017 IGP Symposium

Honolulu, HI

November 16, 2017

# Transforming the grid at a pace and scale that matter

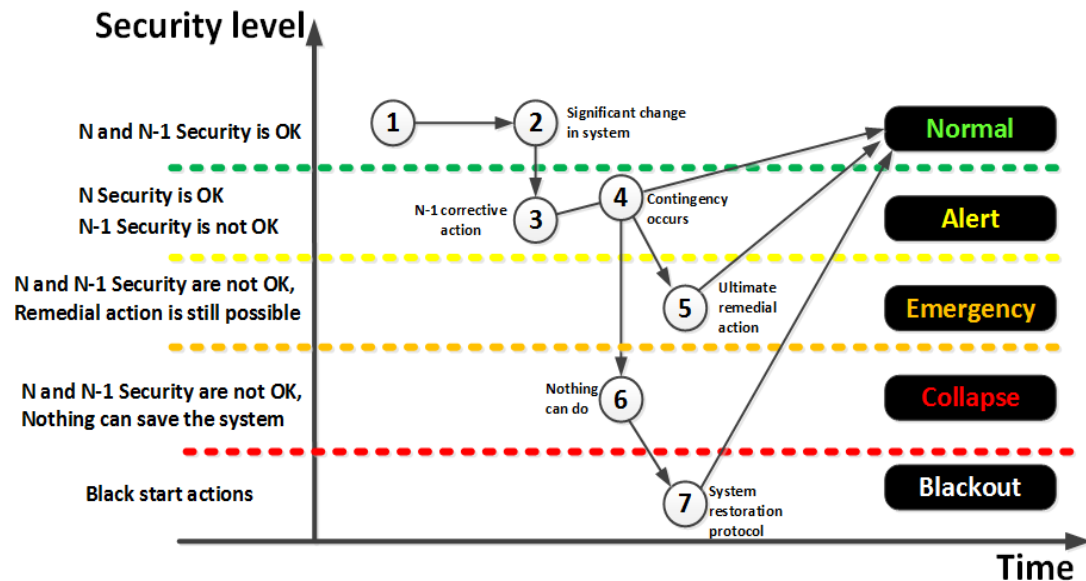


\* Part of a larger synchronous AC power system

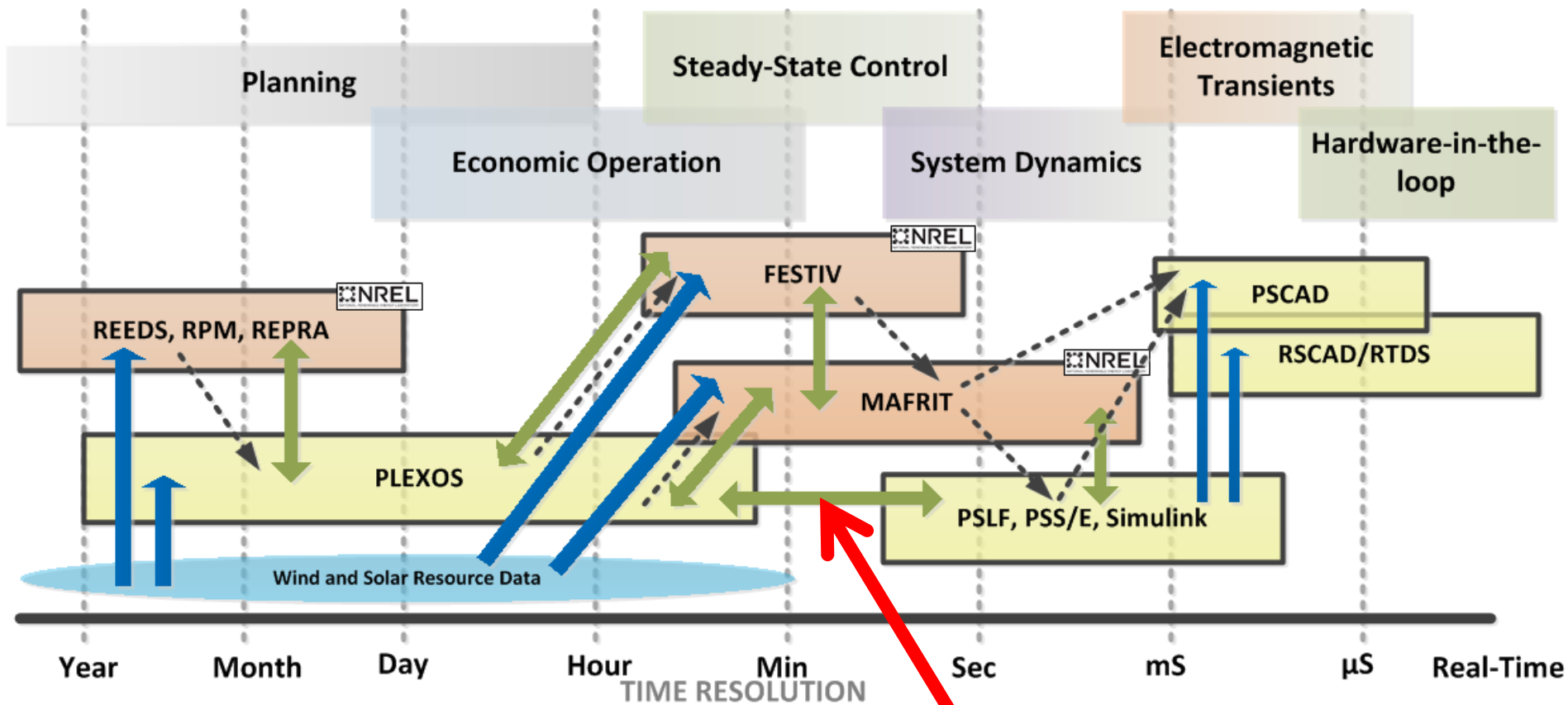
# IGP for Secure and Reliable Island Grids

- 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*

*REPR - Renewable Energy Probabilistic Resource Assessment tool*

*FESTIV – Flexible Energy Scheduling Tool for Integrating Renewables*

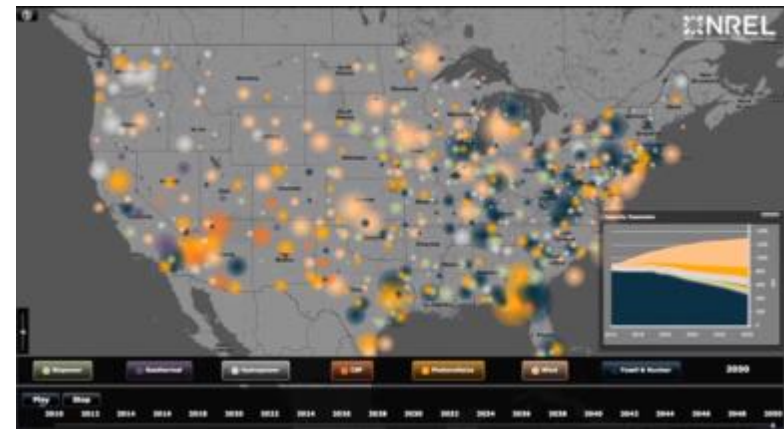
*MAFRIT – Multi-area Frequency Response Integration Tool*

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



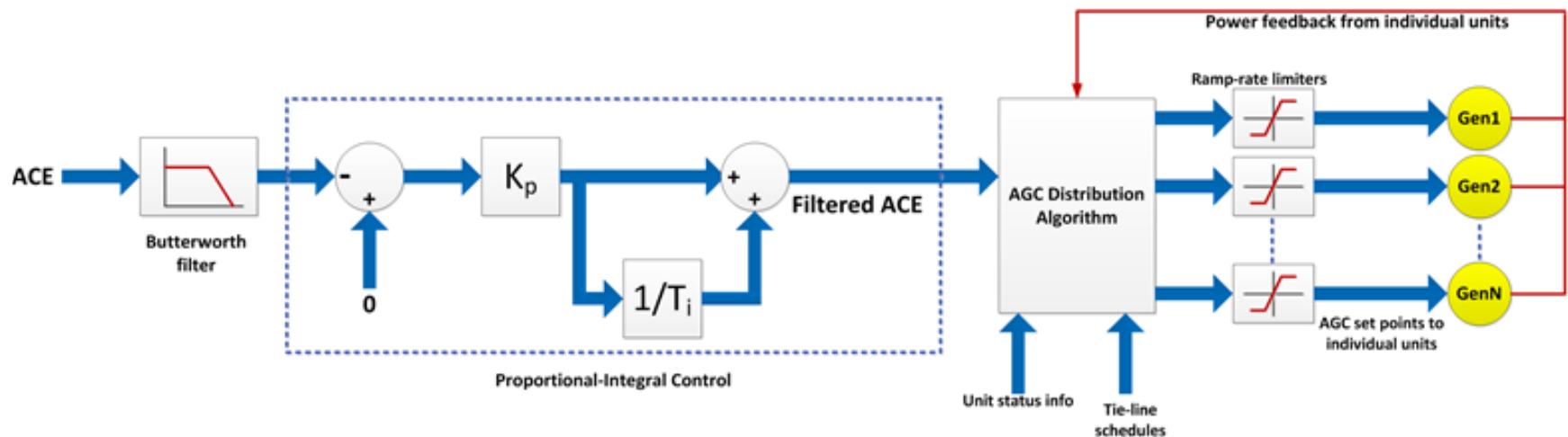
# REPRA and RPM Tools

- 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

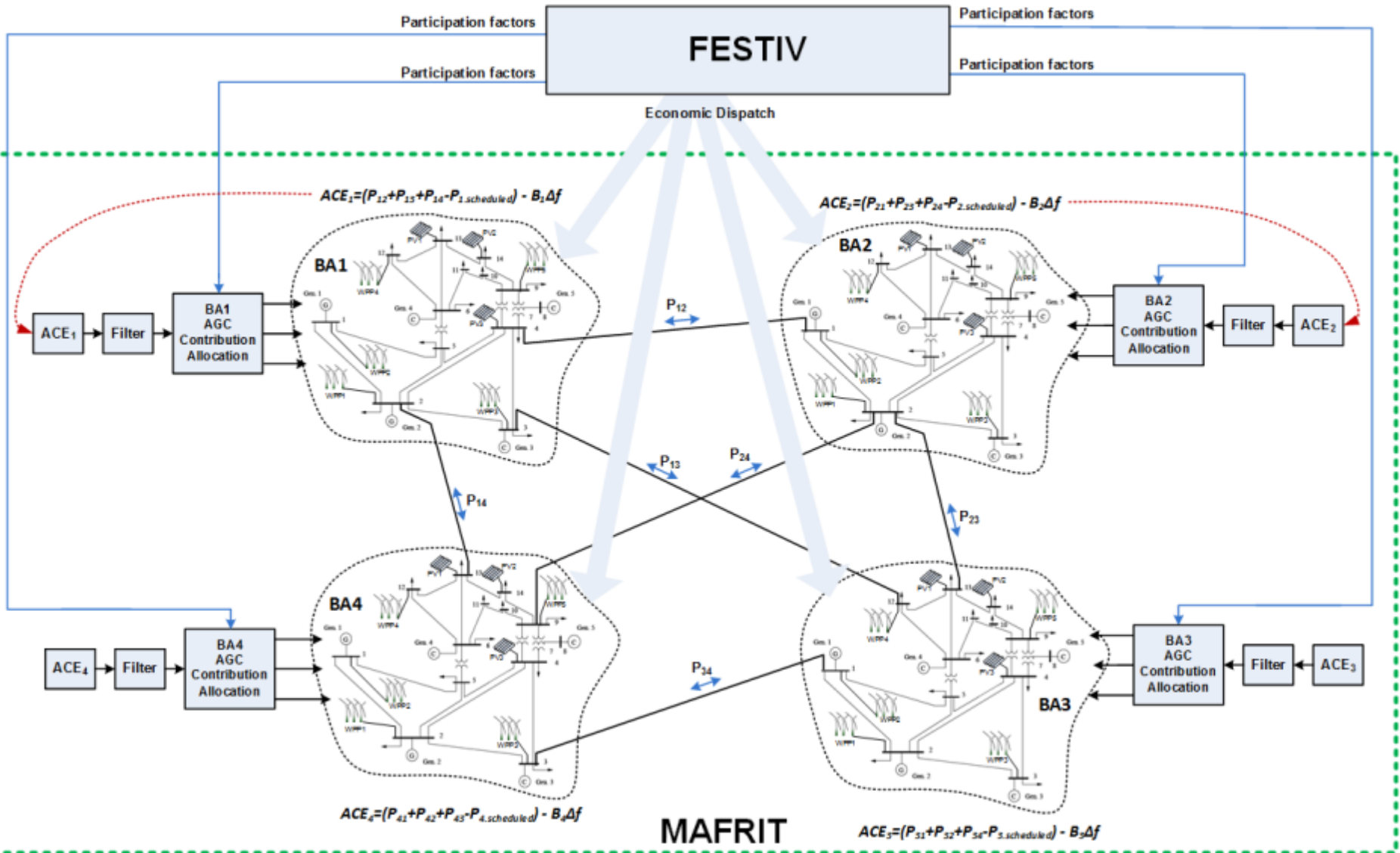


# FESTIV and MAFRIT

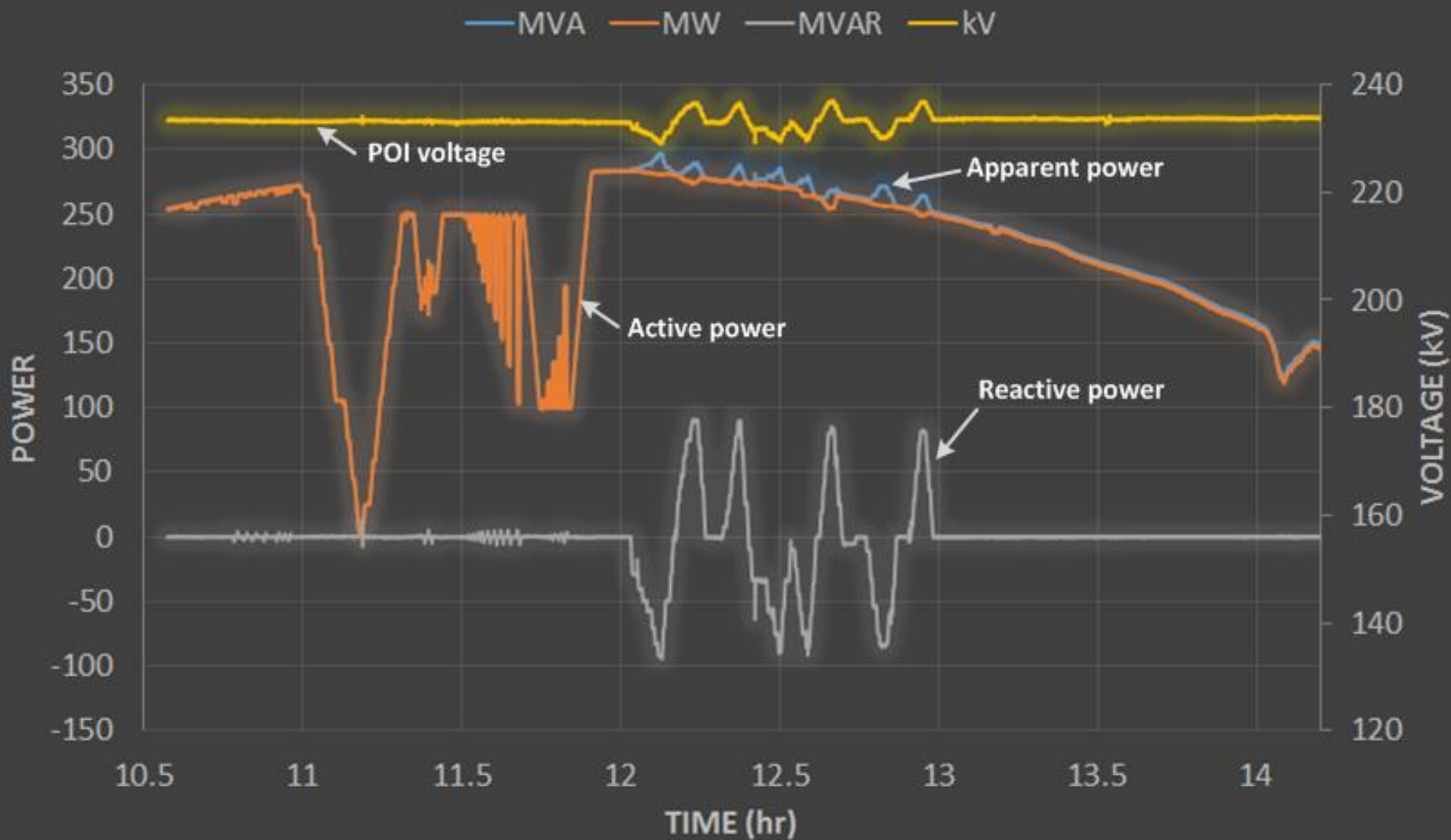
- Flexible Energy Scheduling Tool for Integrating Variable Generation (**FESTIV**) tool
  - Evaluates impacts of variability and uncertainty on power system operations (multiple-timescale, interconnected simulation )
  - Produces both economic and reliability metrics
  - Evaluates trade-offs in economic 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

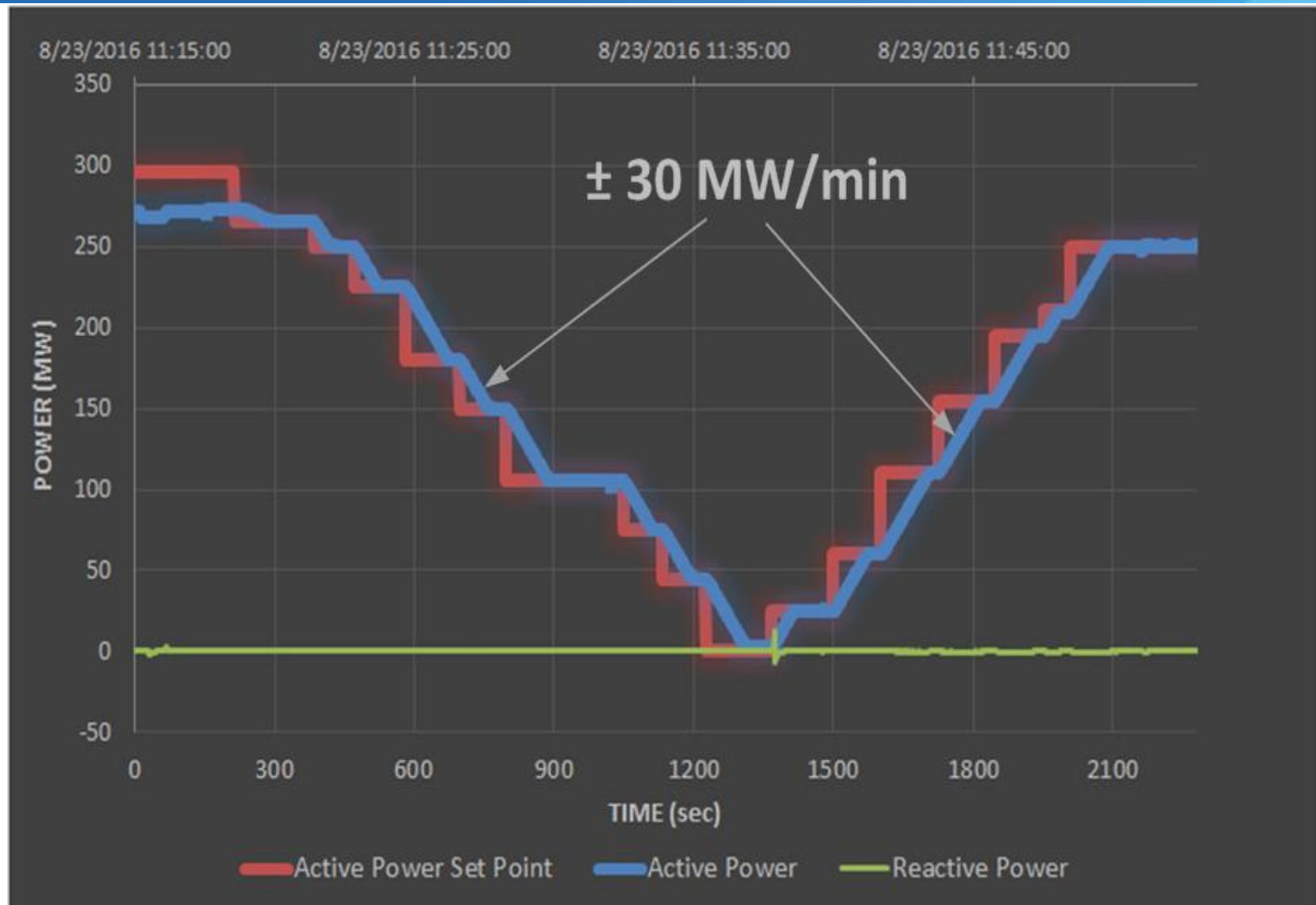


# Snapshot of PREPA AGC Display #4

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

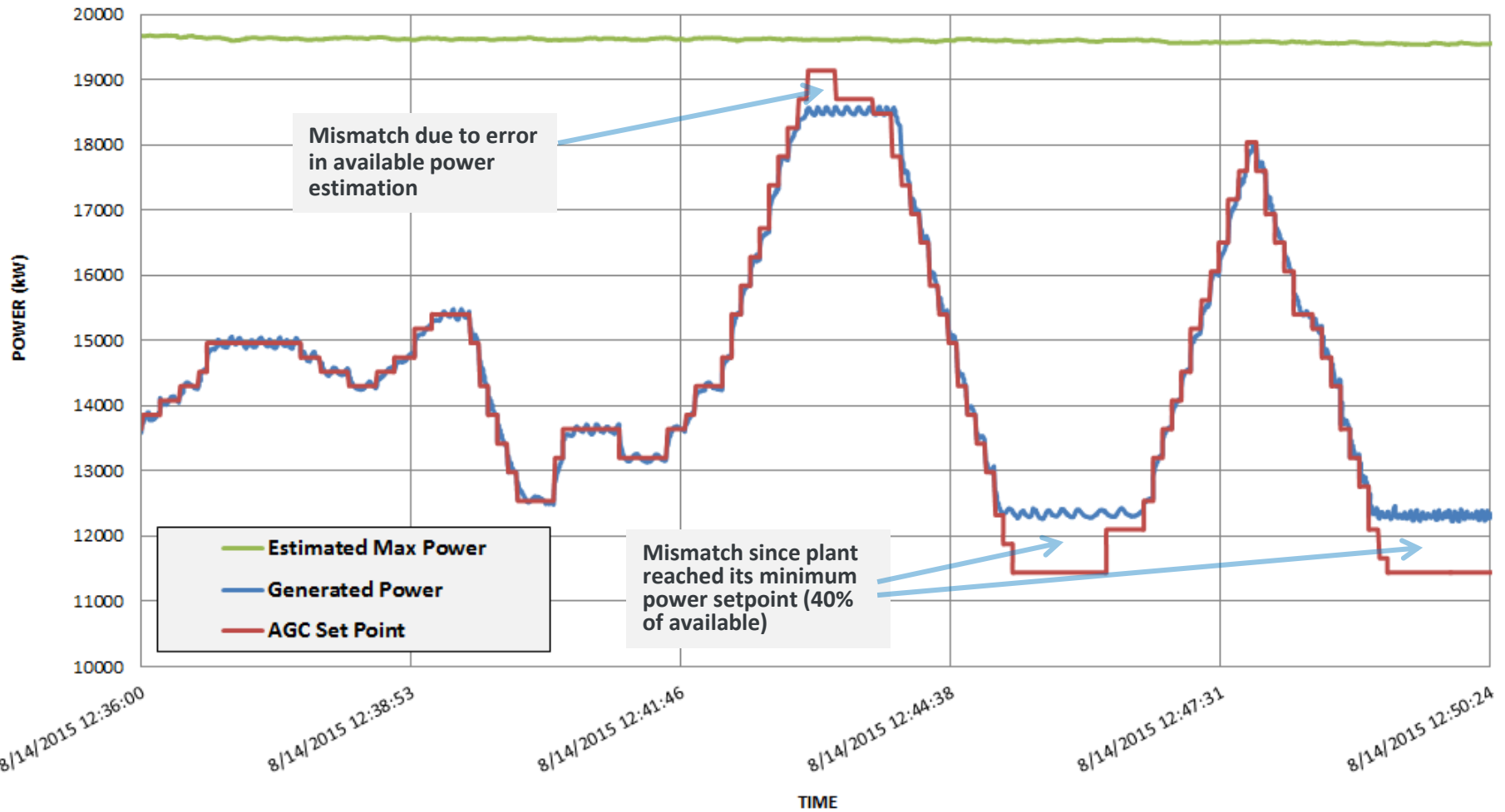
Unit Overview		AGC Control Status		Area Control Error		RESERVES: MW		Emergency Assist		Control State		Control State		Raise		Lower	
SCADA <input checked="" type="checkbox"/> ILEX <input type="checkbox"/>		-3.1 MW		CONTROLLED 85		265		<input type="checkbox"/>		Limited		normal		0.0 MW		0.0 MW	
Time Error -0.3170 sec		Desired Frequency 60.000 Hz		SPINNING (F/S) 262 / 262		262 / 262		FREQUENCY GENERATION 59.973 Hz 2817 MW		Temporary Generation -5.0 MW		boost		0.5 MW		6.7 MW	
OPERATING 957												assist		0.5 MW		6.7 MW	
Unit	Pulse/ SetPt	Generation Actual	Desired	Maximum Capacity	Sustained High	Limits Low	Conn Status	AGC	Remote Status	Remote Control	Base Point Source	Control Type	Operating Mode	Follow Mode			
SAN JUAN 5 CC COMBINED SJS GAS SJS STM	0.0	200	199	220	198	2.0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	TEST	<input type="checkbox"/>			
SAN JUAN 6 CC INDEPENDENT SJS GAS SJS STM	0.0	0.0	100	0.0	0.0	0.0	<input type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
SAN JUAN 7	0.0	87.4	90.0	100	90.0	70.0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	REMOTE	LOCAL	ECONOMIC	FLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
SAN JUAN 8	0.0	0.0	88.9	1.0	1.0	1.0	<input type="checkbox"/>	<input type="checkbox"/>	REMOTE	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
SAN JUAN 9	0.0	83.8	86.3	100	90.0	70.0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	REMOTE	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
SAN JUAN 10	0.0	0.0	70.0	1.0	1.0	1.0	<input type="checkbox"/>	<input type="checkbox"/>	REMOTE	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
PALO SECO 1	0.0	51.6	72.8	53.0	53.0	30.0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
PALO SECO 2	0.0	72.0	50.6	85.0	1.0	1.0	<input checked="" type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
PALO SECO 3	0.0	0.0	185	1.0	1.0	1.0	<input type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
PALO SECO 4	0.0	0.0	180	1.0	1.0	1.0	<input type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	ECONOMIC	FLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
COSTA SUR 3	0.0	0.0	64.9	85.0	1.0	1.0	<input type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
COSTA SUR 4	0.0	0.0	72.5	1.0	1.0	1.0	<input type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	INFLEXIBLE INDEPENDENT	OFF	<input type="checkbox"/>			
COSTA SUR 5	0.0	384	350	390	350	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	ECONOMIC	FLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
COSTA SUR 6	0.0	377	337	380	380	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	ECONOMIC	FLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
AGUIRRE 1	0.0	231	361	243	243	230	<input checked="" type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	ECONOMIC	FLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			
AGUIRRE 2	0.0	389	389	450	390	390	<input checked="" type="checkbox"/>	<input type="checkbox"/>	REMOTE	REMOTE	ECONOMIC	FLEXIBLE INDEPENDENT	ECONOMIC REGULATING	<input type="checkbox"/>			
ECO PP 416	0.0	436	433	530	480	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	REMOTE	REMOTE	ECONOMIC	FLEXIBLE INDEPENDENT	ECONOMIC REGULATING	<input type="checkbox"/>			
AES PP 285	0.0	330	511	325	325	161	<input checked="" type="checkbox"/>	<input type="checkbox"/>	LOCAL	LOCAL	OPERATOR BASE	FLEXIBLE INDEPENDENT	MANUAL DISPATCH	<input type="checkbox"/>			

# Active Power Curtailment Test

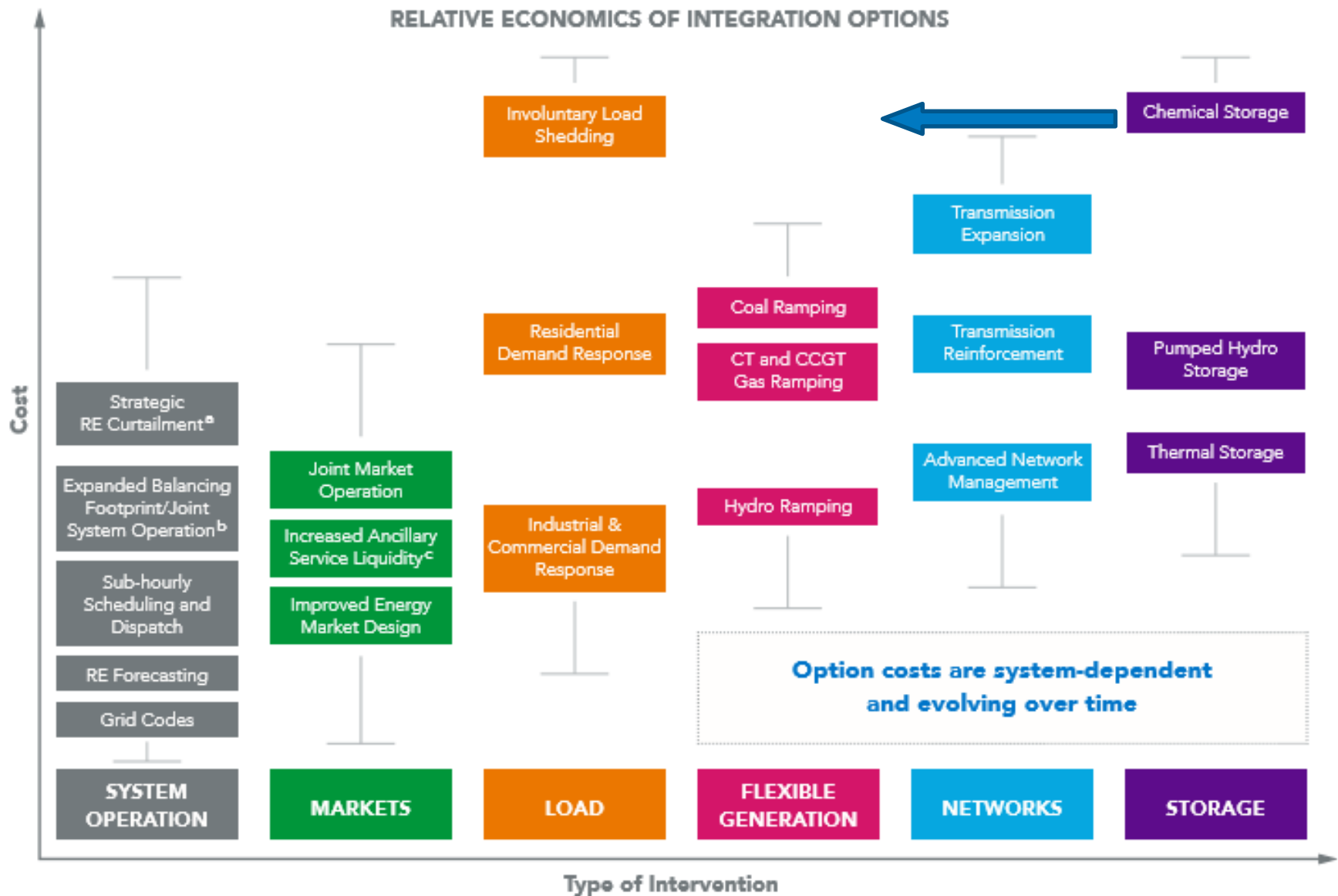


# Plant AGC Performance

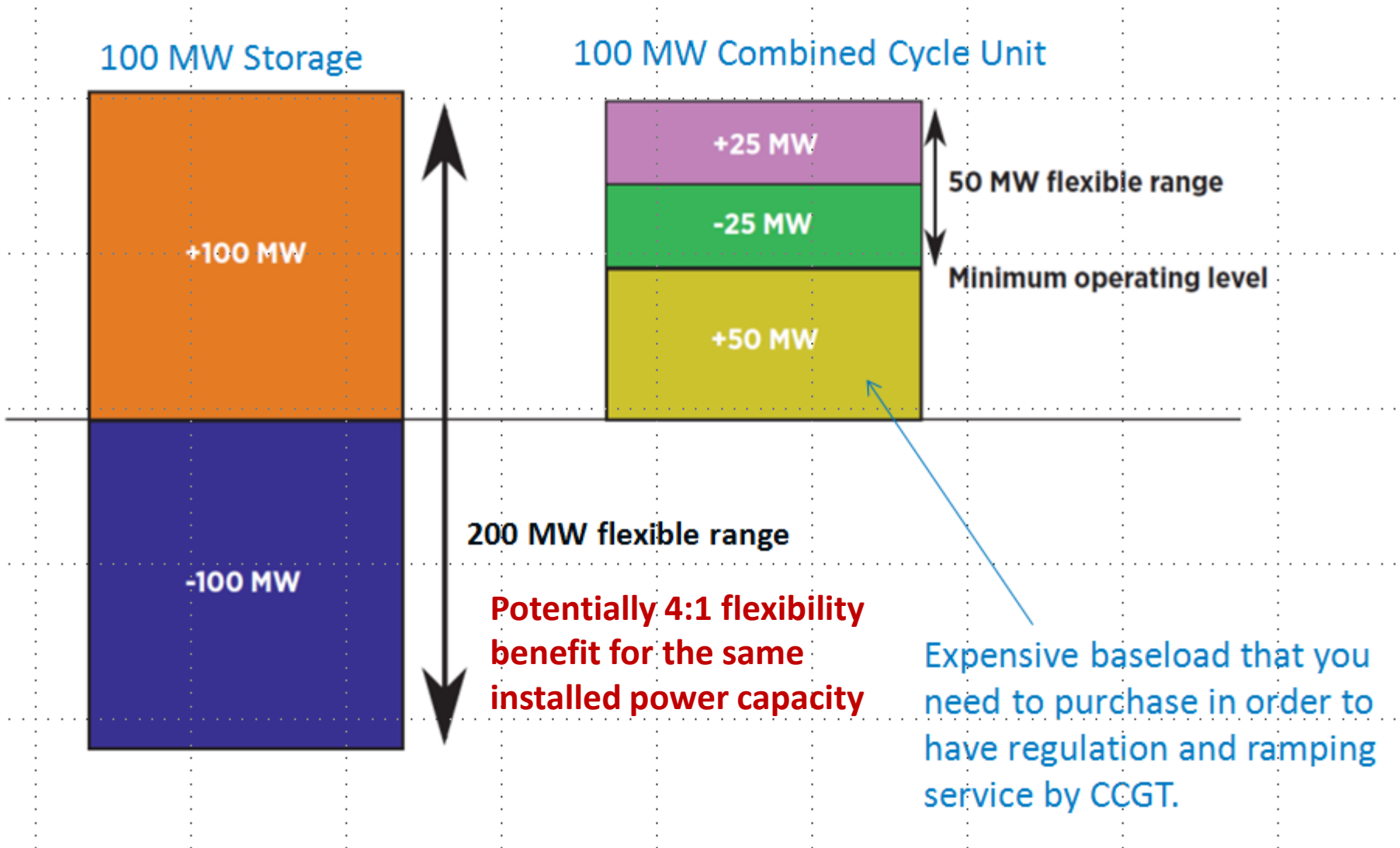
## AGC Test - August 14, 2015



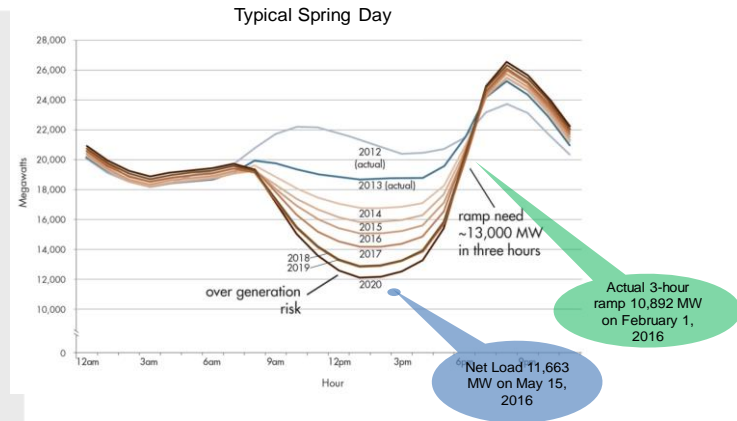
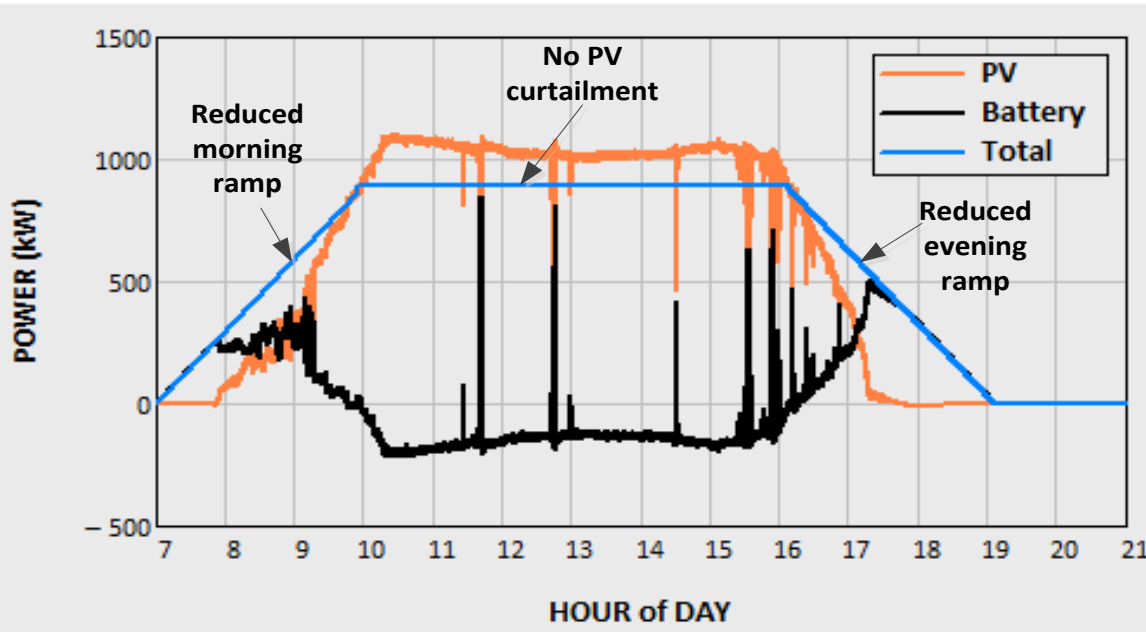
# Changing Flexibility Resources Landscape



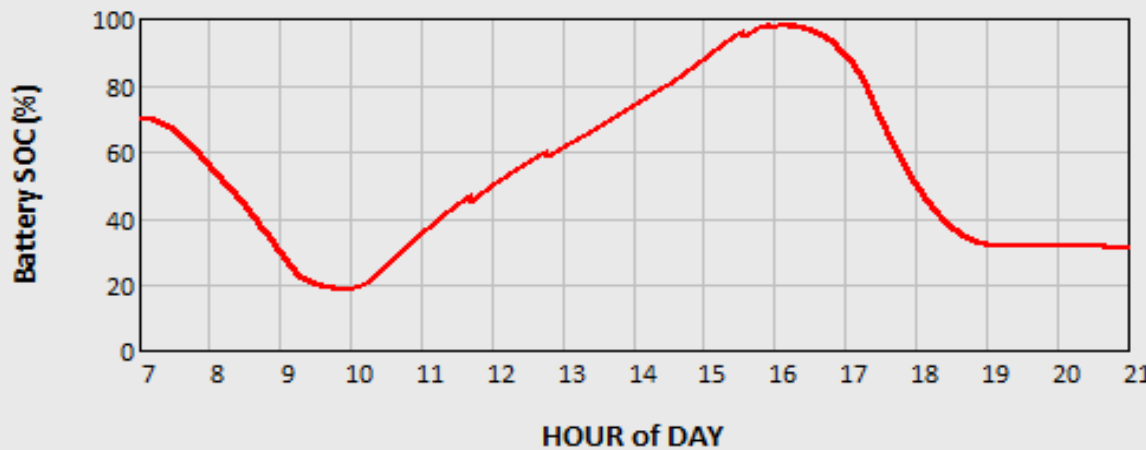
# Energy Storage vs. Combined Cycle for Ancillary Services



# BESS for PV Curtailment Reduction and Ramp Control

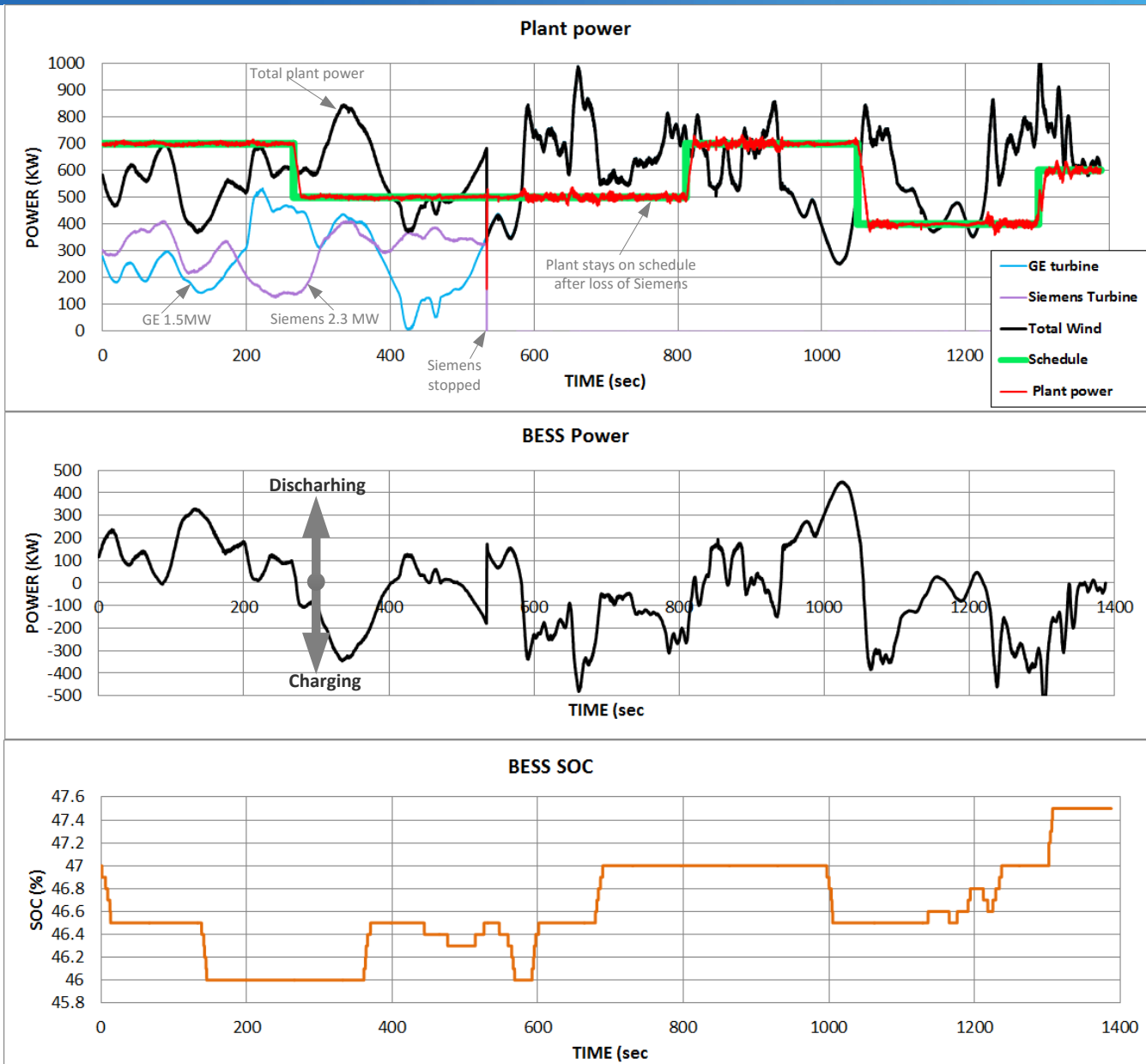


- Reduce PV curtailment
- Limit morning and evening net load ramps
- PV as a dispatchable source and provider of essential reliability services



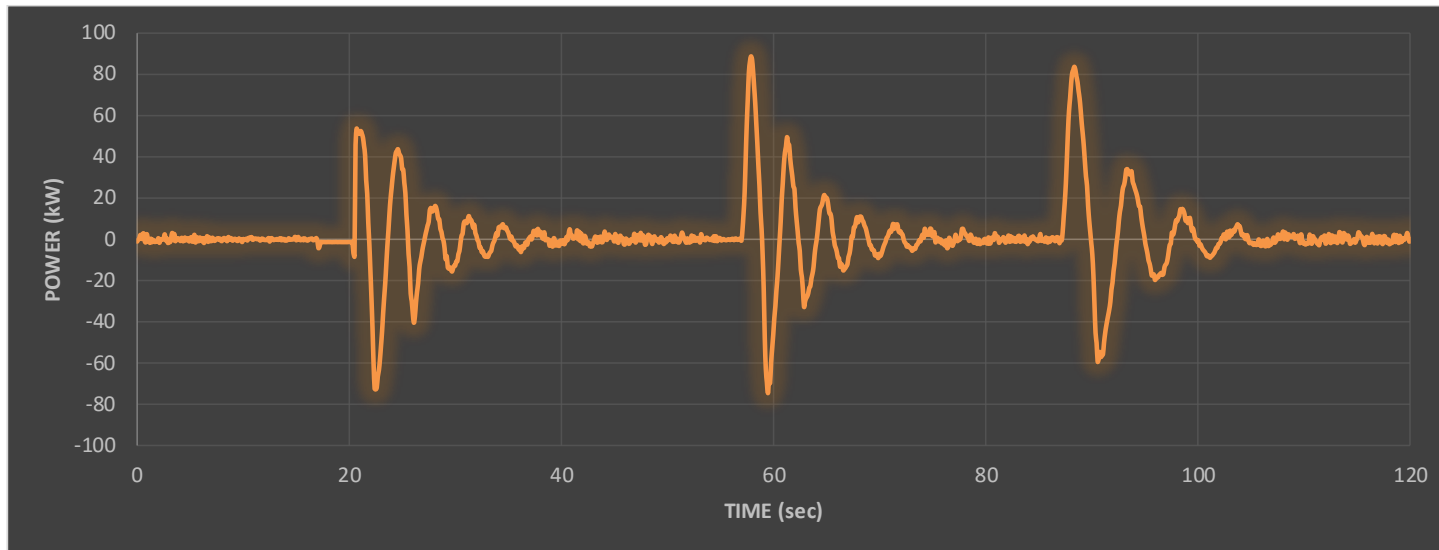


# Dispatchable Hybrid Wind-BESS Plant Demonstration



# BESS Providing POD Response

## Demonstration of Power Oscillations Damping control by BESS



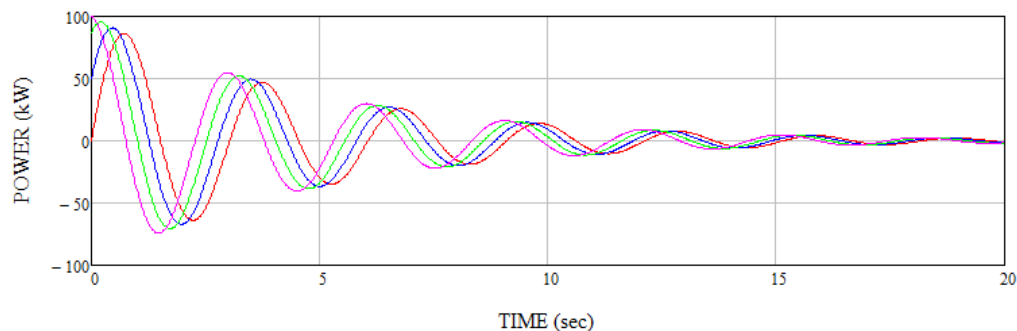
Magnitude of POD response

Frequency of oscillations

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

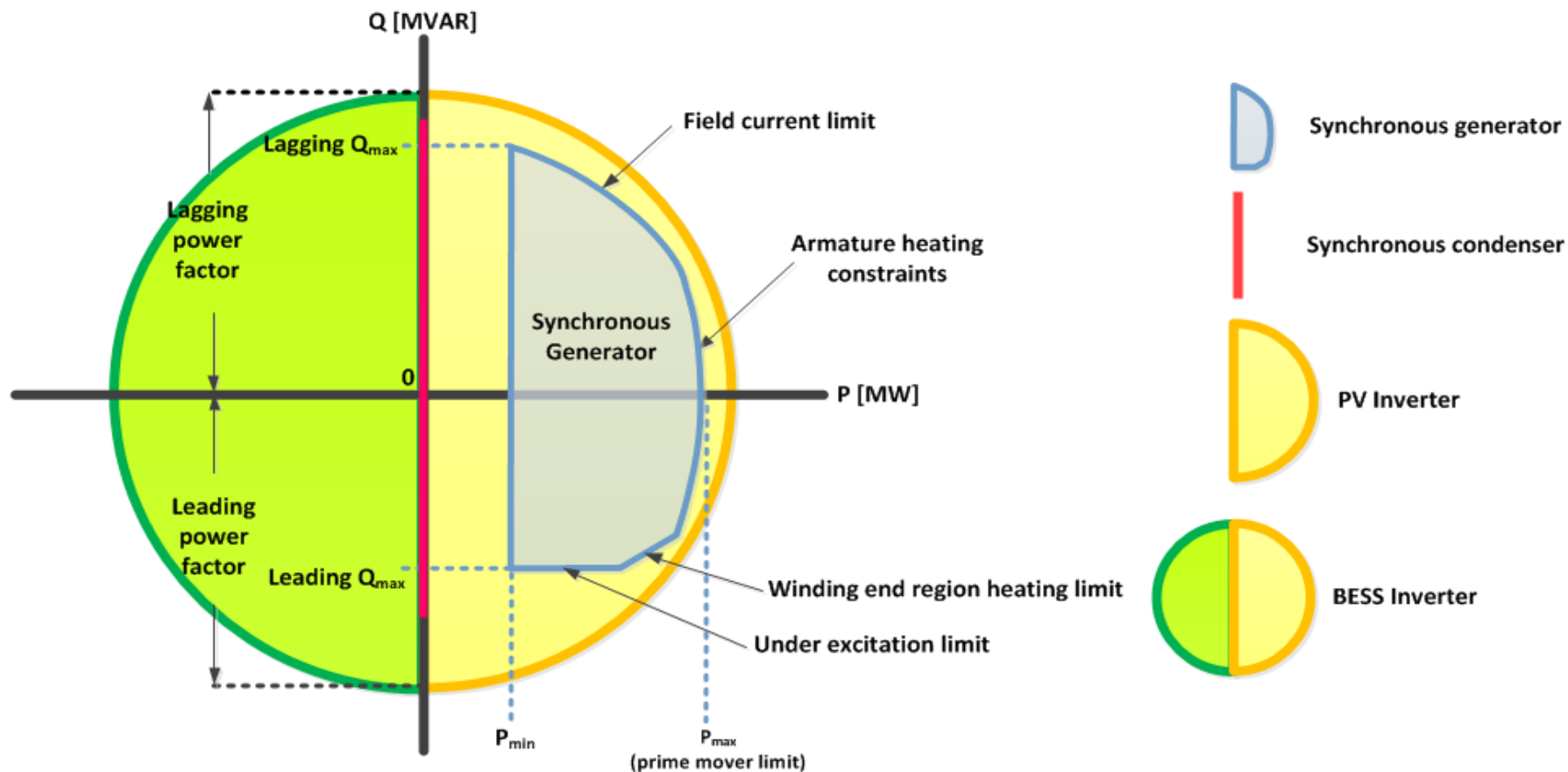
Decay time

Phase angle of oscillations



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

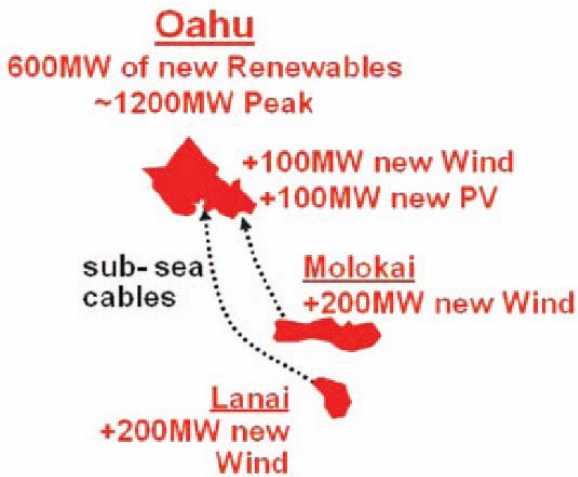
# Reactive Power and Voltage Control Services



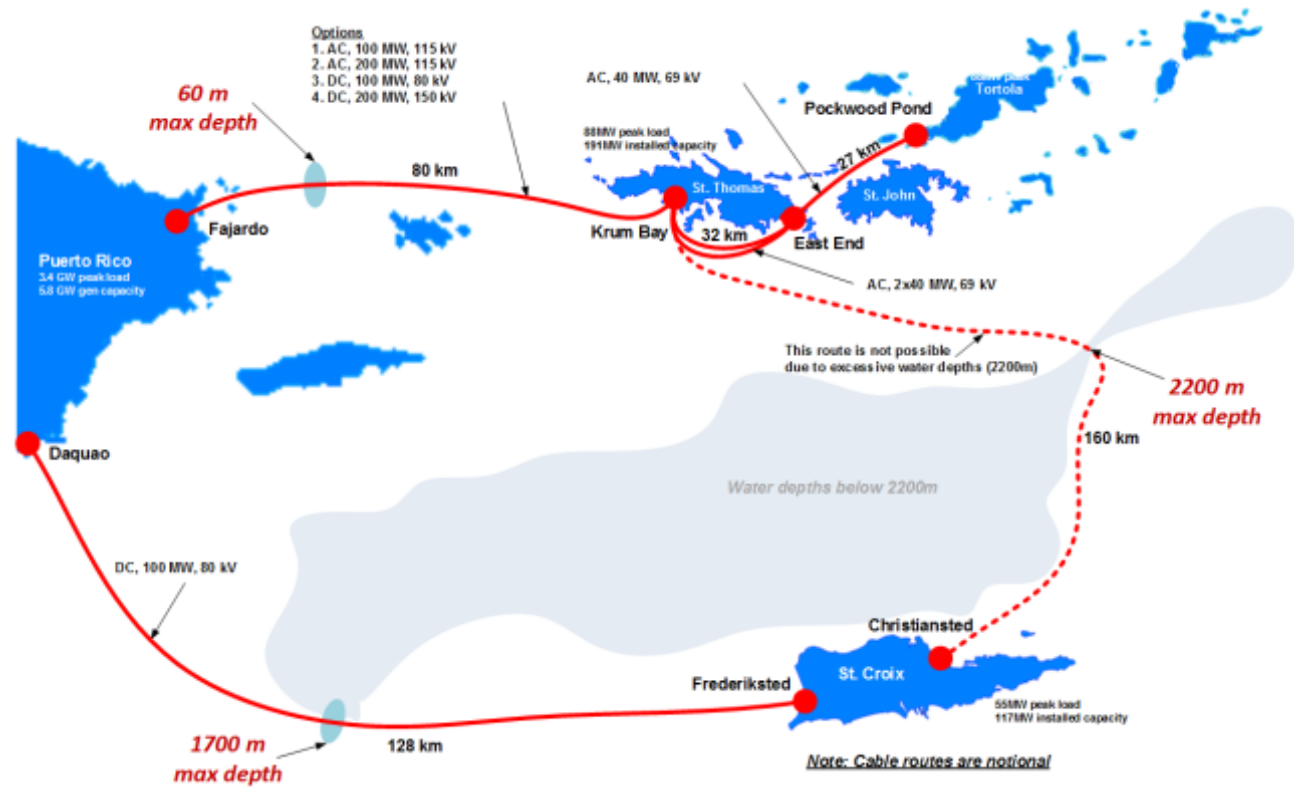
- 2-quadrant P-Q characteristic for wind and PV inverters
- Full 4-quadrant P-Q operation with energy storage

# Submarine Inter-island Power Transmission

## Oahu Big Wind Study



## Puerto Rico – USVI – BVI Study



Thank you!

[www.nrel.gov](http://www.nrel.gov)

