NPCC Distributed Energy Resources/Variable Energy Resources Forum

October 12, 2023, 9:00 a.m. – 12:00 p.m. EDT WebEx Meeting

Dial-In: 415-655-0003 (USA) / 416-915-6530 (Canada)
Guest Code: 24343449508
Password: TPeu2FTF3@8 (87382383 from phone)
WebEx Link

1.0 Distributed Energy Resources (DER) Variable Energy Resources (VER) Forum Topics

1.1 Welcome and Safety Message: Gerry Dunbar, NPCC Director Reliability Standards and Criteria (9:00 am - 9:05 am)
1.2 Antitrust Compliance Guidelines, Public Notice, and Meeting Protocols: Ruida Shu, NPCC Manager of Reliability Standards (9:05 am – 9:10 am)
1.3 NPCC VER/DER Outreach Efforts – Gerry Dunbar, NPCC Director Reliability Standards and Criteria (9:10 am – 9:15 am)
1.4 Utility Perspective and Strategy on Energy Storage for Resiliency and Electrification – Roy Hopkins, Project Manager, Energy Storage, Consolidated Edison of New York (9:15 am – 9:55 am)
1.5 Use of BESS for System Stability Services in Future Power System – Deepak Ramasubramanian, Senior Technical Leader, Electric Power Research Institute (EPRI) (9:55 am – 10:35 am)

Break (10:35 am – 10:40 am)

1.6 Battery Energy Storage Analysis in the NERC Technical Committees – John Paul “JP” Skeath, Senior Engineer, BPS Security and Grid Transformation, North American Electric Reliability Corporation (NERC) (10:40 am – 11:20 am)
1.7 Storage resource participation in CAISO – Danny Johnson, Market Design Sector Manager, California Independent System Operator (CAISO) (11:20 am – 12:00 pm)
1.8 Closing – Gerry Dunbar

Northeast Power Coordinating Council, Inc. (NPCC)

Antitrust Compliance Guidelines

It is NPCC's policy and practice to obey the antitrust laws and to avoid all conduct that unreasonably restrains competition. The antitrust laws make it important that meeting participants avoid discussion of topics that could result in charges of anti-competitive behavior, including: restraint of trade and conspiracies to monopolize, unfair or deceptive business acts or practices, price discrimination, division of markets, allocation of production, imposition of boycotts, exclusive dealing arrangements, and any other activity that unreasonably restrains competition.

It is the responsibility of every NPCC participant and employee who may in any way affect NPCC's compliance with the antitrust laws to carry out this commitment.

Participants in NPCC activities (including those participating in its committees, task forces and subgroups) should refrain from discussing the following throughout any meeting or during any breaks (including NPCC meetings, conference calls and informal discussions):

- Industry-related topics considered sensitive or market intelligence in nature that are outside of their committee's scope or assignment, or the published agenda for the meeting;
- Their company's prices for products or services, or prices charged by their competitors;
- Costs, discounts, terms of sale, profit margins or anything else that might affect prices;
- The resale prices their customers should charge for products they sell them;
- Allocating markets, customers, territories or products with their competitors;
- Limiting production;
- Whether or not to deal with any company; and
- Any competitively sensitive information concerning their company or a competitor.

Any decisions or actions by NPCC as a result of such meetings will only be taken in the interest of promoting and maintaining the reliability and adequacy of the bulk power system.

Any NPCC meeting participant or employee who is uncertain about the legal ramifications of a particular course of conduct or who has doubts or concerns about whether NPCC's antitrust compliance policy is implicated in any situation should call NPCC's General Counsel and Corporate Secretary, Mr. Damase Hebert at (646) 737-2335 or dhebert@npcc.org.

Distributed Energy Resources and Variable Energy Resources Forum Disclaimer Statement

1. General

Any information presented [at NPCC forums] is for informational purposes only. NPCC accepts no responsibility for the accuracy of such presentations, or for your reliance on any information contained within the content available through such forums. Discussions represent a wide range of views and interests of the participating individuals and organizations. Statements made during discussions do not necessarily reflect those of NPCC.

2. Vendors

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Public Announcement

RSC and DER/VER Forum Meetings, WebEx, and Conference calls:
Participants are reminded that this meeting, WebEx, and conference call are public. The access number was posted on the NPCC website and widely distributed. Speakers on the call should keep in mind that the listening audience may include members of the press and representatives of various governmental authorities, in addition to the expected participation by industry stakeholders.

Meeting Logistics

Participants will be muted upon entry, and you are encouraged to use the “Chat” feature of the WebEx if you wish to ask a question. The questions will be answered by the presenter at the end of each presentation. NPCC DER/VER Forum will be recorded, the recording and meeting material will be posted on the DER Forum section of the NPCC website.

Thank you for your cooperation.

NPCC 2023 Outreach Activities

Gerry Dunbar
Director Reliability Standards and Criteria

October 12, 2023

NPCC, Inc.

NPCC 2023 – 2026 Strategic Plan

Strategic Focus Area

Reliably Integrate Resources Brought Forward by Decarbonization Objectives

NPCC 2023 DER/VER Forums:

- April
  - Transmission Integration
- May
  - IEEE-2800 – Standard for Interconnection of Inverter Based Resources
- August 10
  - Offshore Wind
- October 12
  - Battery Storage

NPCC 2023 – 2026 Strategic Plan

Strategic Focus Area

Reliably Integrate Resources Brought Forward by Decarbonization Objectives

NPCC Collaboration and Communication:

- NERC ERO State and Provincial Outreach Group (EROSOG)
  - Inform policy makers on key issues impacting grid reliability
  - Coordinate Outreach on ERO-wide initiatives
- NPCC DER/VER Guidance Document
  - Development Initiated by the NPCC BOD
  - Guidance and Information
  - DER/VER Reliability Reporting Form

Grid Security Conference (GridSecCon 2023)

- October 17-20 Quebec City, Canada
- Co hosted by NERC, the E-ISAC and NPCC
- Gov’t/Industry Cyber and Physical Security Leaders
  - Expert Training Sessions
  - Best Practices and Lessons Learned
  - Threat Mitigation Programs
- Topics:
  - Cyber and Physical Security
  - Supply Chain
  - Special Topics

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Utility Perspective and Strategy on Energy Storage for Resiliency and Electrification

Roy Hopkins

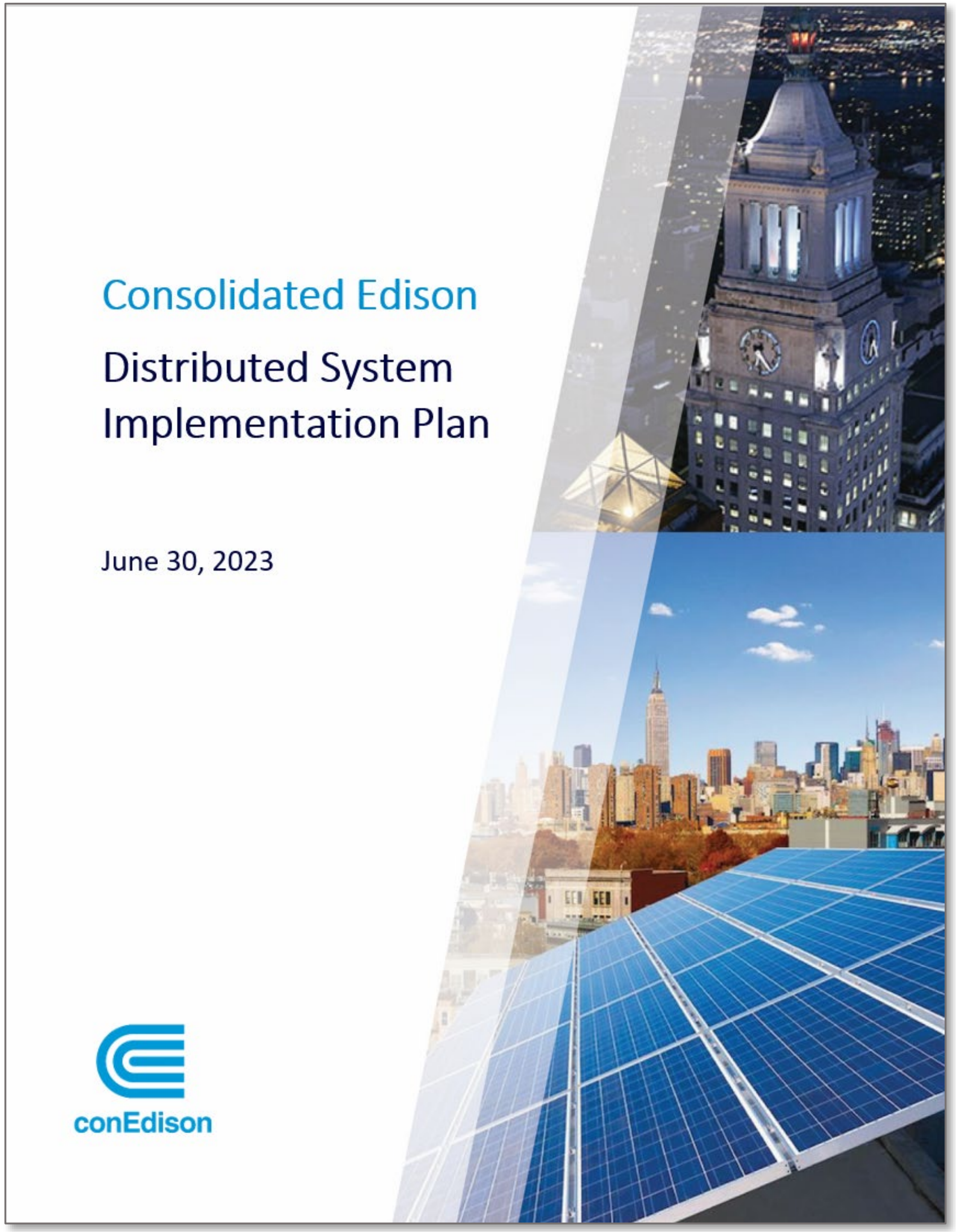
October 12th, 2023 - WebEx Presentation

About Our Company

Founded in 1823, Con Edison has fueled and sustained the growth of Greater New York for two centuries.

Today, we operate one of the world's largest energy delivery systems, and provide electric, gas, and steam service for the 10 million people who live in New York City and Westchester County.

conEdison 200 years



- Con Edison recently issued its 4th Distributed System Implementation Plan ("DSIP") to increase customer choice and promote a sustainable and clean energy future.
- The DSIP supports the New York State's Climate Leadership and Community Protection Act ("CLCPA")
- **Energy Storage is critical part of both the New York State CLCPA and the Con Edison DSIP**

Full report is available on
[NY.gov under Department of Public Service]

Summary of CLCPA Goals Plus Zero Emission Vehicle Regulation Targets

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40 percent emissions reductions in absolute terms from 1990 levels by 2030, 85 percent emissions reductions by 2050

70 percent renewable energy by 2030, 100 percent clean energy by 2040

9,000 MW of offshore wind by 2035

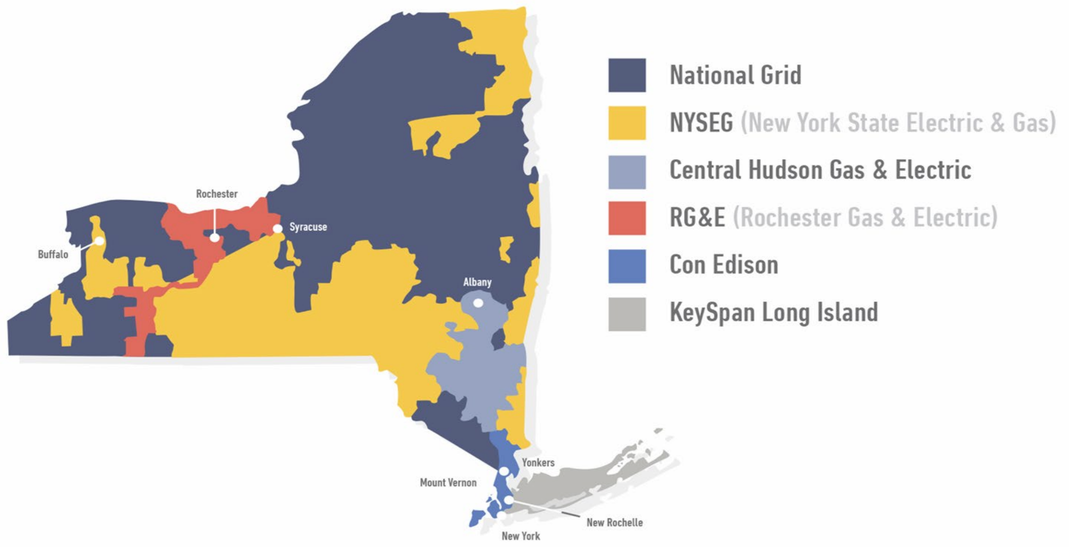
6,000 MW of solar energy by 2025

6,000 MW of energy storage capacity by 2030

Reduce energy consumption by 185 trillion British thermal units (BTUs) from the state's 2025 forecast

850,000 light-duty ZEVs by 2025

New York State and New York City Energy Storage Goals



Public Service Commission

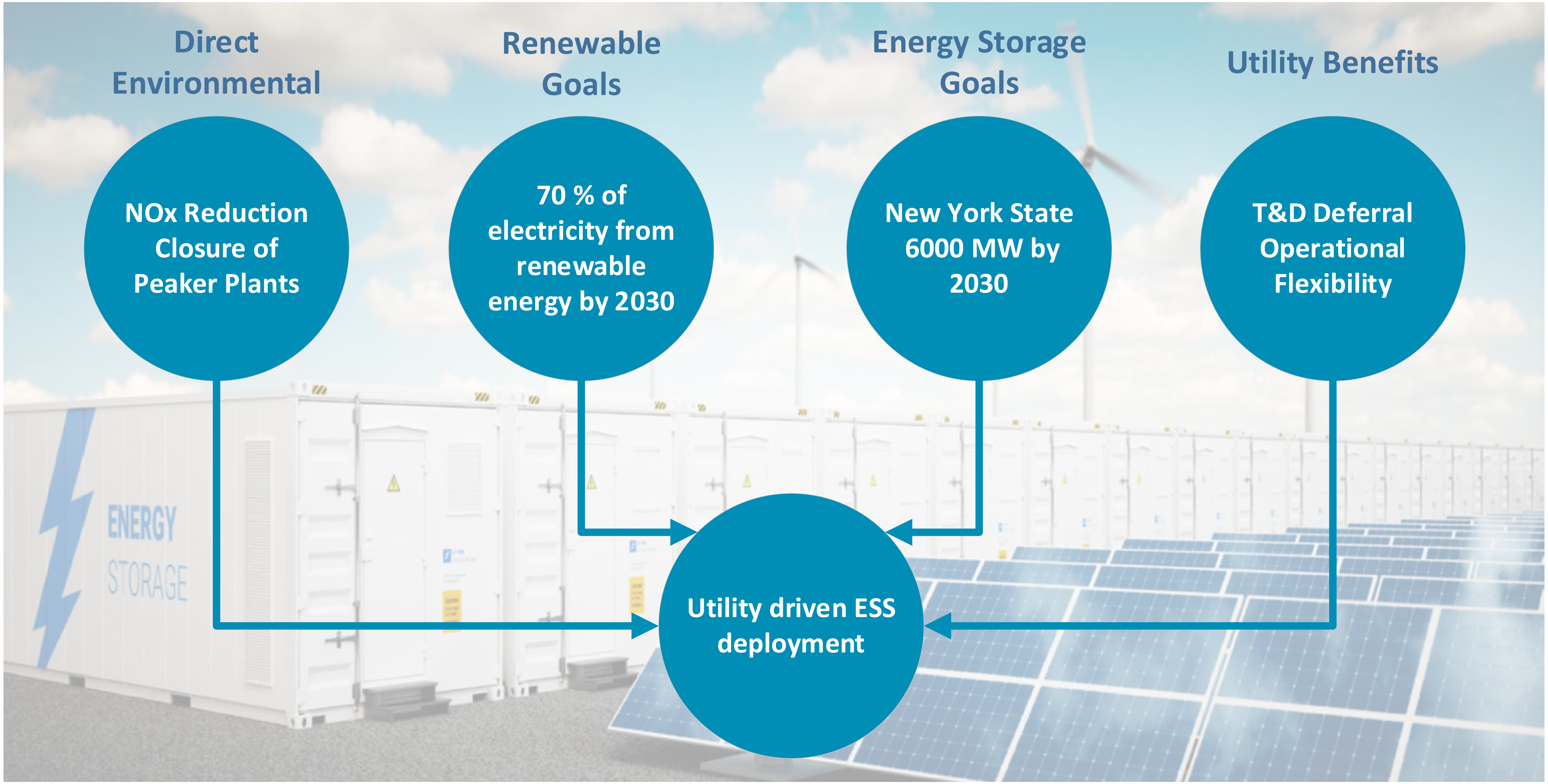
- 1,500 MW by 2025
- 6,000 MW by 2030

City of New York Mayors Office

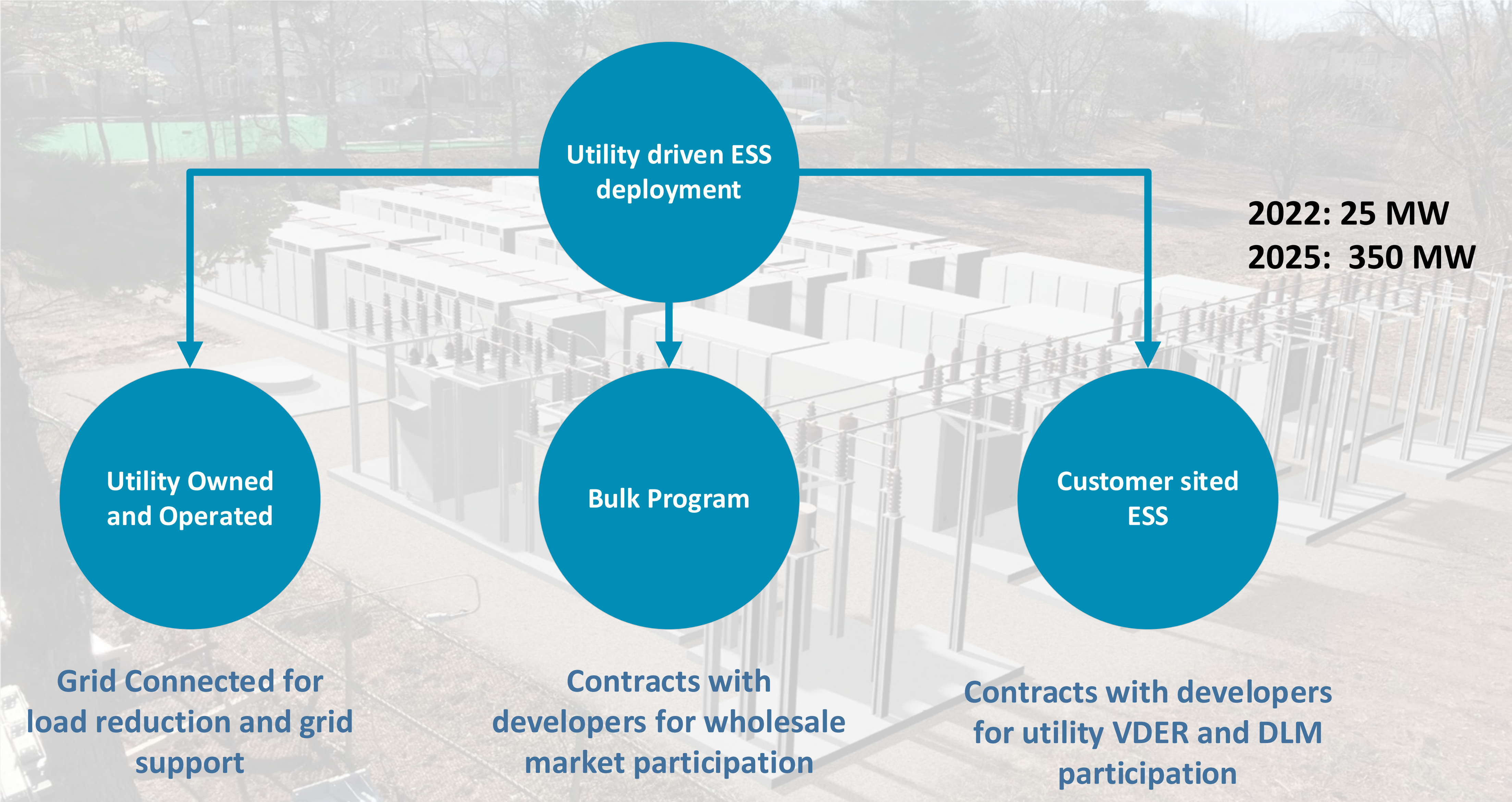
- 100 MWh by 2020
- Max 12-month permitting
- 500 MW by 2025

Energy Storage is a corner stone technology to achieving New York State Landmark "Climate Act" or CLCPA objectives.

Utility Drivers for Energy Storage



Utility Driven Energy Storage



Customer Sited Energy Storage

As of end of 2022 Con Edison has interconnected 499 customer energy storage system ("ESS") projects, totaling 24.9 MW of capacity

Multi MW in the interconnection queue

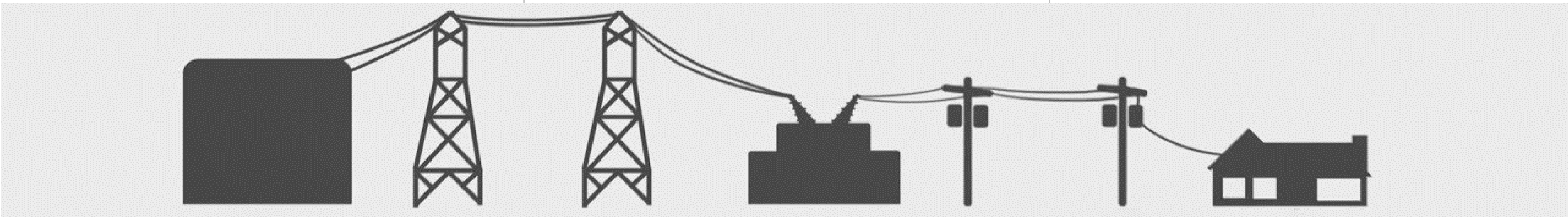
Today, developers favor systems that are

- Greater than 0.75MW to qualify for Coned's Value of Distributed Energy Resources (VDER) program
- 5 MW or less to fall under the New York State Standardized Interconnection Requirements (SIR)

Bulk Program

The Utility purchases dispatch rights to storage systems larger than 5MW and interconnected to either transmission or distribution systems

Transmission	Distribution	Customer
Peaking capacity	Infrastructure deferral	Demand charge reduction
Energy arbitrage	Voltage support	Reliability and back up
Black start/voltage support	Avoided renewable curtailment	Voltage support
Frequency regulation	Energy arbitrage	Electric vehicle charging
Renewable balancing	Renewable balancing	



General Arrangement of the Con Edison Bulk Energy Storage Program

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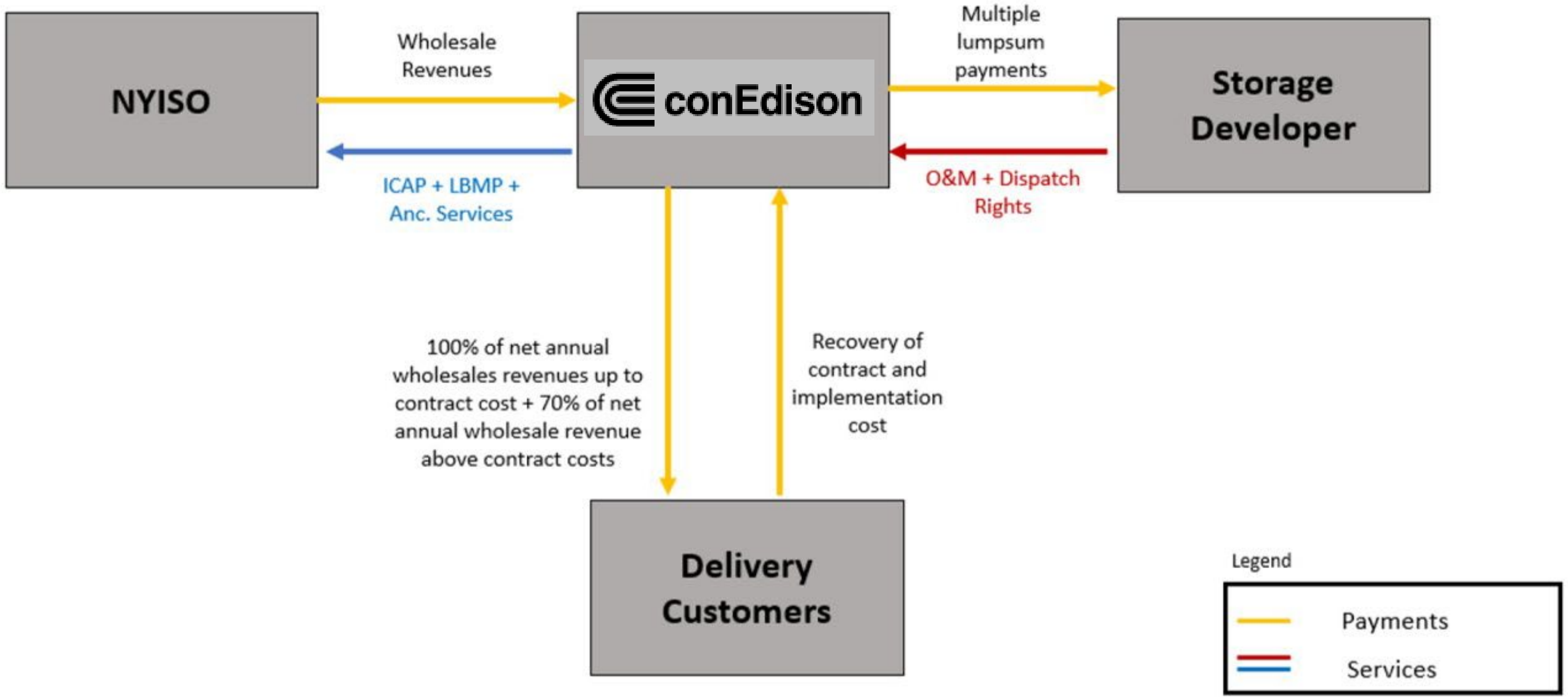
- CECONY issues RFP and evaluates responses based on technical, qualitative, and quantitative criteria
  - Each project must be over 5MW
  - Four-hour duration
  - Projects must be front-of-the-meter
  - Electrically connected in Con Edison's service territory
  - Commercially available technology only



Utility Integration: Ideation to Operations

<u>Customer Energy Solutions- *Engineers*</u>

Manages energy storage projects from initiation, design, construction, integration, and commissioning to operations and maintenance of assets. Coordinates the multiple stakeholders (internal & external) throughout the project's life.

<u>Energy Control Center- *Energy Dispatchers*</u>

Remotely monitors and operates Energy Storage systems. They have operational jurisdiction over battery assets and the station equipment that feeds them. They are responsible for dispatch of the asset when necessary.

<u>Substations Operations - *Senior Operators* (Local 1-2 & 3)</u>

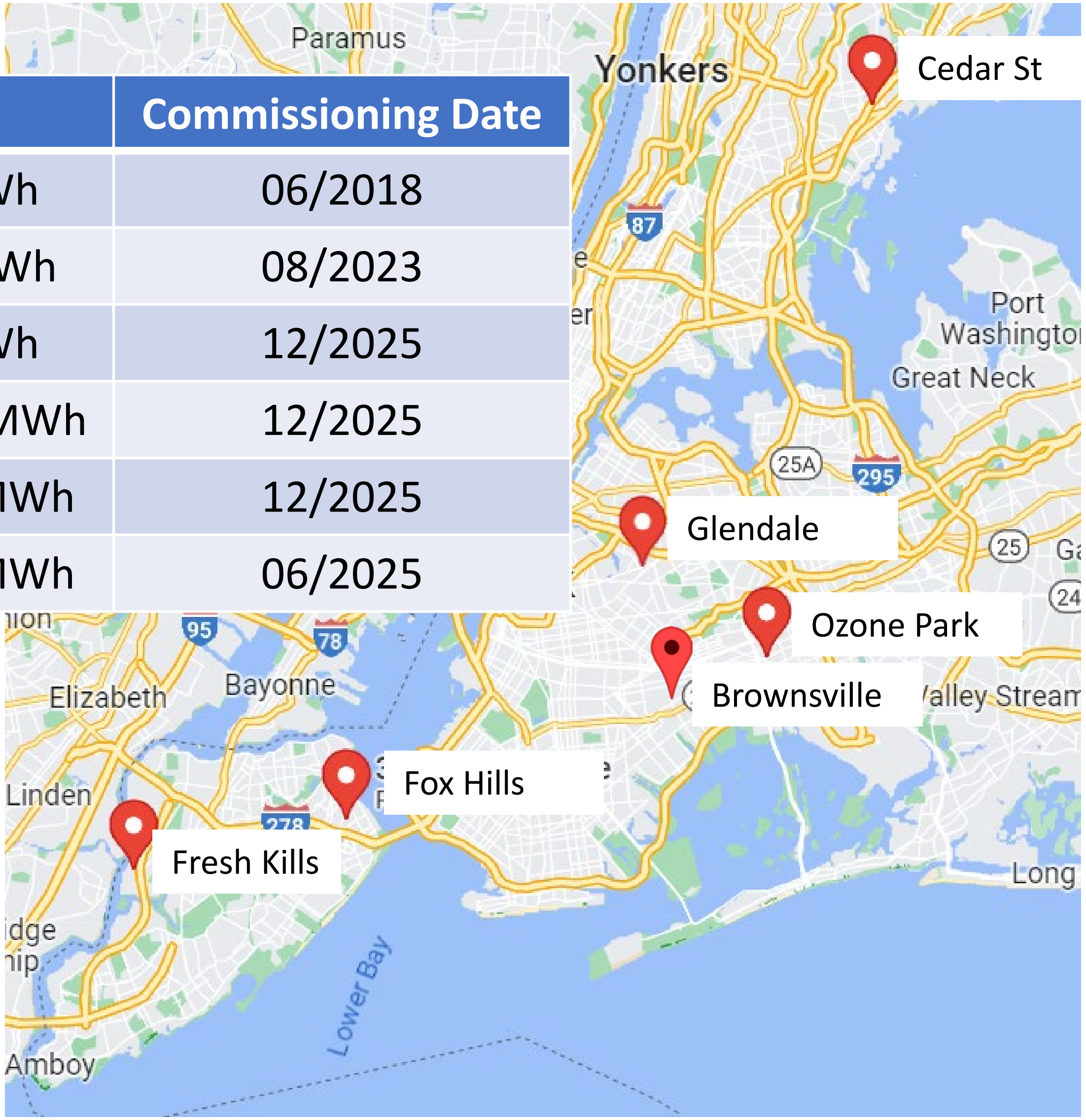
Maintains safety during and after installation by providing proper isolation, protection, and issuing work permits. Manages and responds to real-time alarms with timely notifications. Switches traditional station equipment when required.

Developing Utility Owned ESS: In-House EPCM Structure

ENGINEERING	**Design: Electrical, Mechanical, Civil, Fire Protection** Customer Energy Solutions; Central Engineering; Distributed Engineering.
PROCUREMENT	**Secure: Contracts, Materials, Equipment, and Batteries** Customer Energy Solutions; Law Department; Procurement; Supply Chain; Substations Planning.
CONSTRUCTION	**Building, Installing & Commissioning** Central Construction ; Construction Services; Cranes and Riggings; Substation Operations; Protective Systems Testing; Substation Maintenance.
MAINTENANCE	**Full operations** Environmental Health and Safety; Facilities; PST; Substation Maintenance and Operations; The Learning Center; System Operations; Substation Operations.

Utility Owned and Operated ESS

Project	Size	Commissioning Date
Ozone Park	2MW / 12MWh	06/2018
Fox Hills Substation	7.5MW / 30MWh	08/2023
Cedar Street Substation	4MW / 12MWh	12/2025
Fresh Kills Substation	11.6MW / 46.4MWh	12/2025
Glendale Substation	5.8MW / 23.2MWh	12/2025
Brownsville	5.8MW / 23.2MWh	06/2025



Complexity of Developing Storage in Dense Urban Areas

- Real estate availability in NYC
  - Developing brownfield properties
  - Often in residential areas
  - Early and frequent community outreach
- Fire Department of New York City (FDNY) has specific requirements – FDNY Rule 3 RCNY 608
  - TM-1 application for owners and developers
  - TM-2 application for manufactures
    - Influenced by UL9540A test report
  - B28 Certificate Of Fitness holders

Fox Hills ESS - Rendering

Training Drills with Internal and External AHJ

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Ozone Park ESS is situated in a residential area between a church and a public school

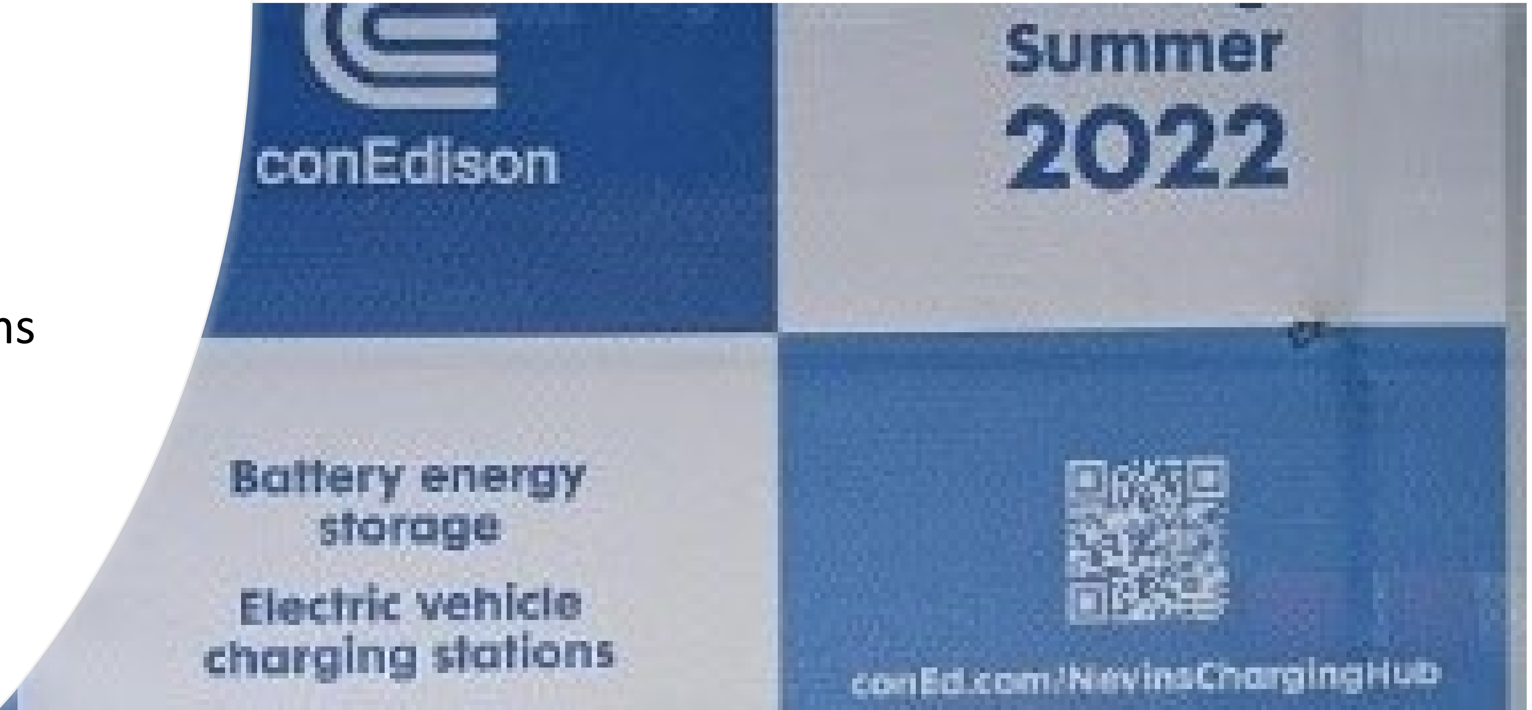
In 2022 we conducted a 1st of its kind Emergency Preparedness Drill with the NYC Hazmat Branch, which is made up of:

- FDNY
- New York City – Office of Emergency Management
- FBI
- NYPD
- US 24th Civil Support Team (Army)
- Con Edison Chemical Biological Radiological & Nuclear (CBRN) Team

Local residences were invited to watch and got educational hand-outs

Ending Notes

- Con Edison has adopted a multi pronged approach to energy storage
- We are still learning to take full advantage of the fast response and flexibility of the systems
- We include the community from the start, and we continue to educate communities and emergency response teams throughout the life of the systems



Thank you!

Roy Hopkins

Project Manager - Energy Storage

CES - Distribution Planning

Consolidated Edison of New York Inc

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646.660.0643

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Use of BESS for System Stability Services in Future Power System

Deepak Ramasubramanian
dramasubramanian@epri.com

NPCC DER-VER Forum
12th October 2023

Acknowledgement and Disclaimer

- The material covered in this presentation is based on work supported in-part by:
  - EPRI Member funded research, and
  - U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Numbers DE-EE0008776, DE-EE0009019, DE-EE0009025, DE-EE0002437. The views expressed herein do not necessarily represent the views of the U.S. Department of Energy or the United States Government

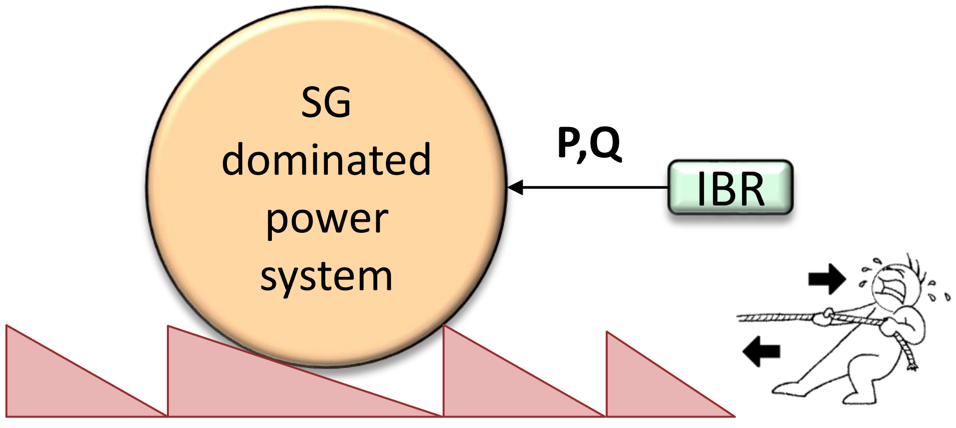
- Collaborators from EPRI:
  - Lakshmi Sundaresh, Vikas Singhvi, Parag Mitra, Stavros Konstantinopoulos, and Wenzong Wang

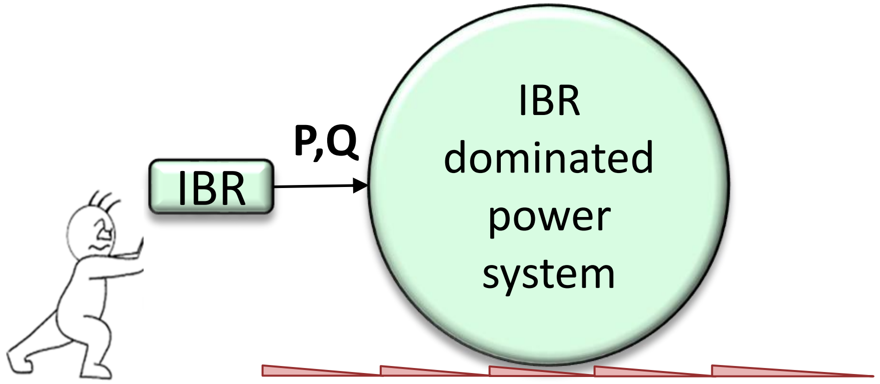
Evolving system needs expected from Inverter Based Resources (IBRs)

Power System	System needs from IBR
Past: SG dominated system	Unity power factor, minimal fault ride-through …
Present: Increased penetration of IBRs	Automatic voltage control, frequency response, V/F ride-through …
Future: IBR dominated system	Without relying on SGs, provide the above services and more (fast frequency response, maintain system stability…)

Moving toward an inverter dominated power system, IBRs will gradually substitute SGs in providing grid services and ensuring grid reliability

Challenges of IBRs to provide services





- Majority of today's IBR control is designed to work in a stiff system
  - Changes in IBR injected current do not 'move' the stiff system
  - Changes in system cause IBR to 'move' in tandem
- This behavior has recently been labeled as grid following (GFL)

- In IBR dominated power system:
  - Increased elasticity in the grid
  - Changes in IBR injected current will 'move' the system
  - This movement in system will itself cause IBR to 'move' in tandem
- This increased interaction is to be stabilized for IBR to deliver expected needs

Could grid forming (GFM) IBRs be the solution to provide services in an inverter dominated grid?

Technology terminology in this presentation

Legacy IBR

- Injects active power at unity power factor
- Provides no grid support services

Conventional IBR

- Has capability to provide both frequency and voltage response
- Typically at a plant level and full delivery over multiple seconds

Enhanced IBR

- Delivers full frequency and voltage response within 1s of event
- Could survive loss of last synchronous machine

Future IBR

- Is capable of blackstart
- Could potentially single handedly survive extreme events

GFL

Most power networks are at this position

Few power networks use this capability

Very few power networks ask and use this capability

Not in use (apart from few small islands); Area of active research

GFM

GFL and GFM – refer to a single inverter
IBR – refers to entire plant containing numerous inverters

Services from IBRs

- Gigawatts (GWs) of IBRs in the present power network, whose capability is underutilized

- Hundreds of GWs of IBRs presently in the interconnection queue for whom, utilization/delivery of full capability is either not required, or is optional (market product).

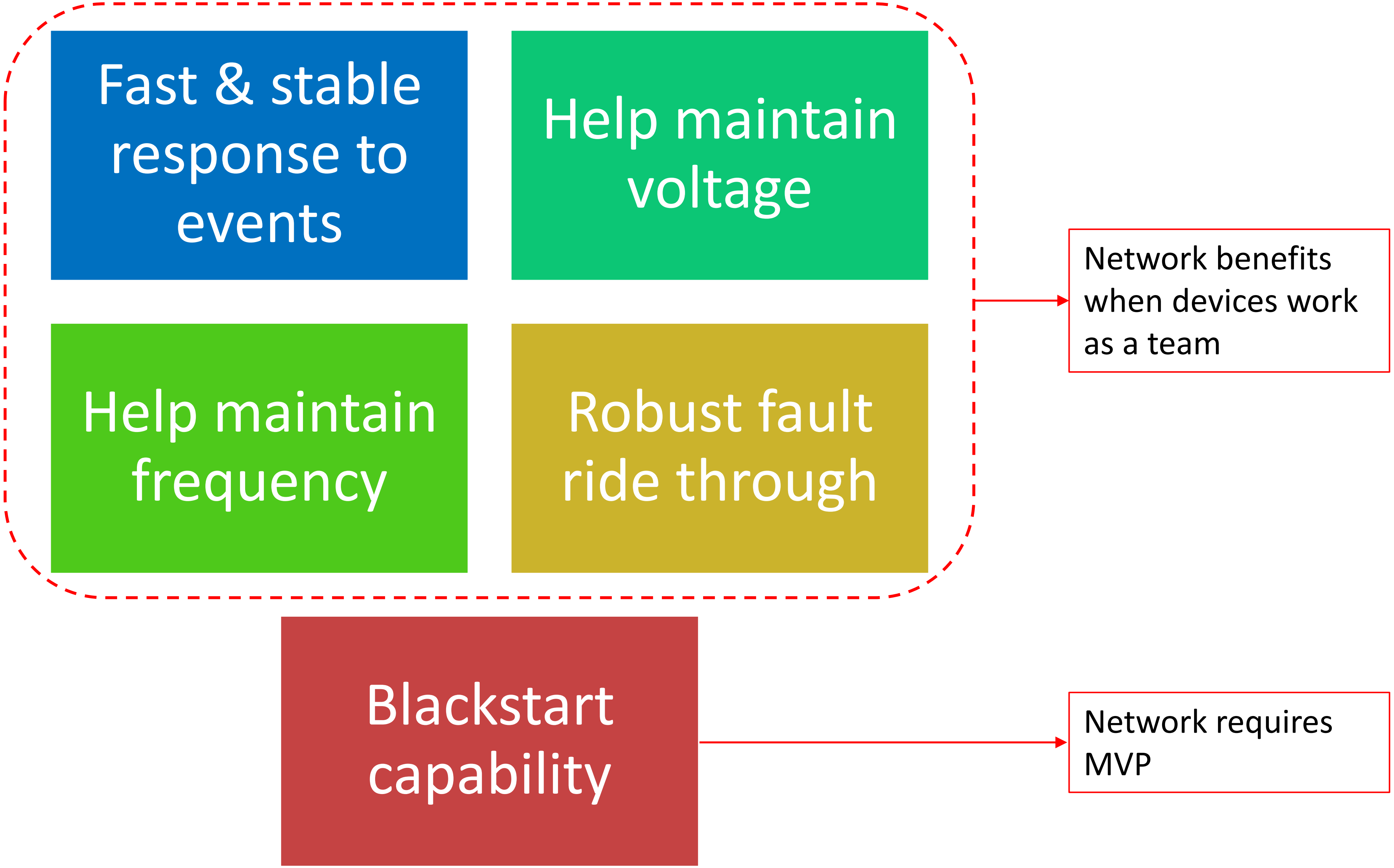
- Underutilization of capability today can lead to increased burden and timeline of capability provision on future IBR.

- Power system operation is a team sport
  - Improved reliability when each player contributes a little, in a beneficial manner
  - Entire burden cannot (and should not) fall on the MVP*

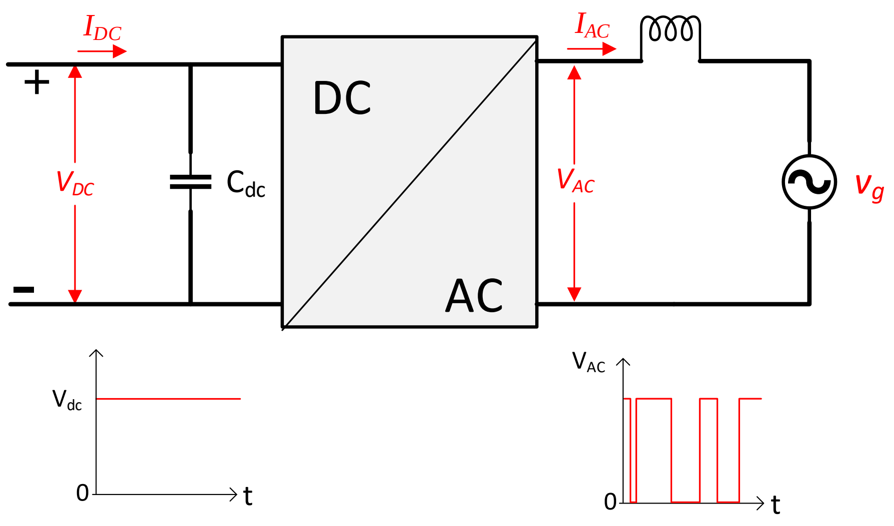
Subsequent sections of presentation discusses concepts of how each IBR could contribute in a beneficial manner

*Most Valuable Player

Categories of services from IBRs



Uniqueness of BESS IBR when compared to other IBRs



- DC side: stiff voltage source
- Stiffness is dependent on the DC link capacitance
- Note: $i_c = C\frac{dV_{dc}}{dt}$
- If $C_{dc} \rightarrow \infty$: Any magnitude of current will not result in a change in voltage

- In an inverter, magnitude of generated ac voltage is dependent on magnitude of dc voltage
- If dc voltage changes, then ac voltage can change
- BESS, because of its source characteristics, offers a stiff dc source
- Other IBRs may not offer such stiff dc side characteristics.

Improved voltage and frequency response from BESS

Example requirements from around the world

National Grid UK

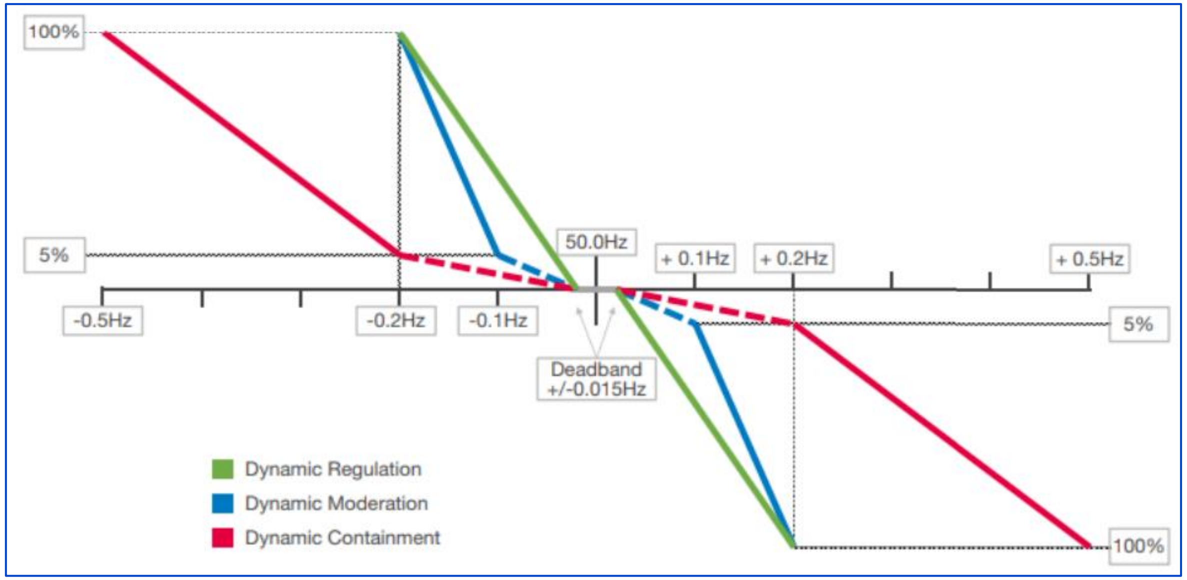


Figure source: https://www.nationalgrideso.com/document/276606/download

- Dynamic containment and dynamic moderation services to be delivered within 1s
- Piecewise droop with minimum value of 0.21%!!
- Expectation is to deliver a linear (and not switched) response

AEMO

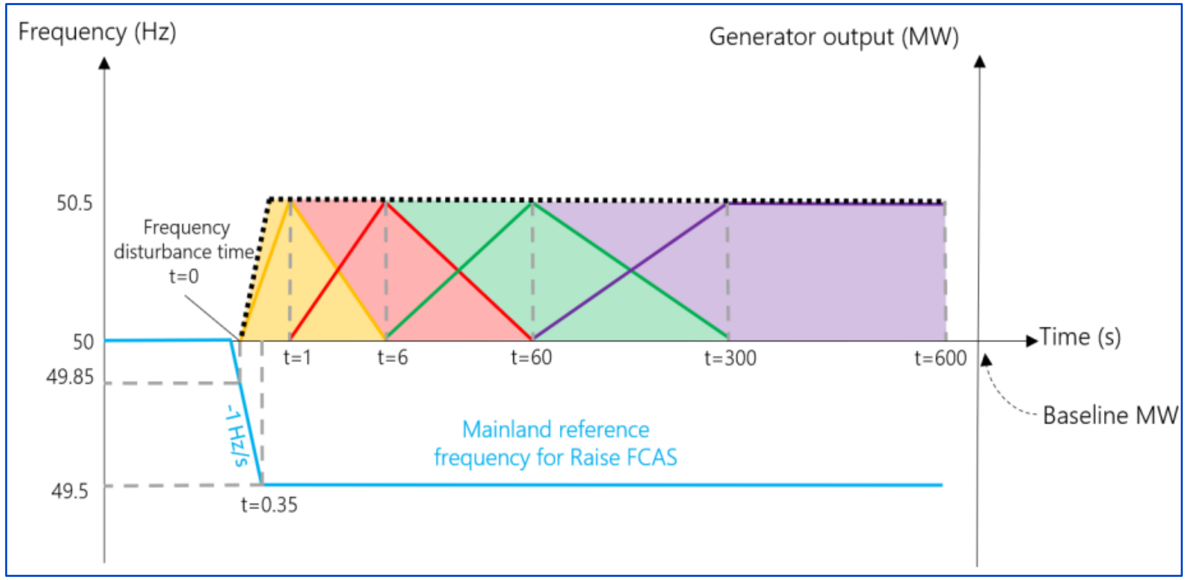


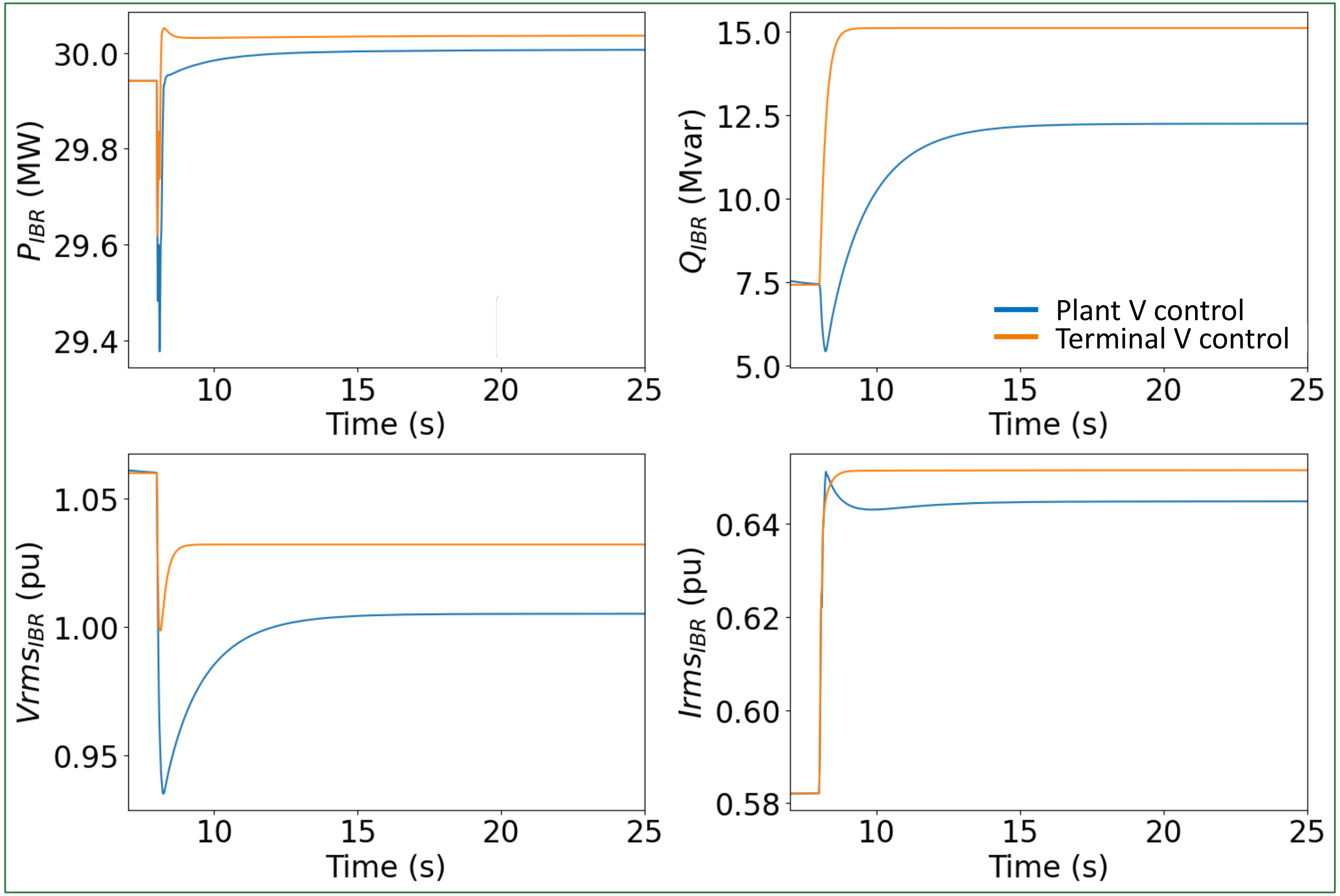
Figure source: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/amendment-of-the-mass/final-determination/market-ancillary-services-specification---v80-effective-9-oct-2023.pdf?la=en

- Very fast frequency control ancillary service to be delivered within 1s
- Minimum droop of 1.7%
- Expectation is to deliver a linear (and not switched) response

IEEE 2800 – 2022 has similar requirements for capability related to fast frequency response

Bringing about fast voltage response at device level

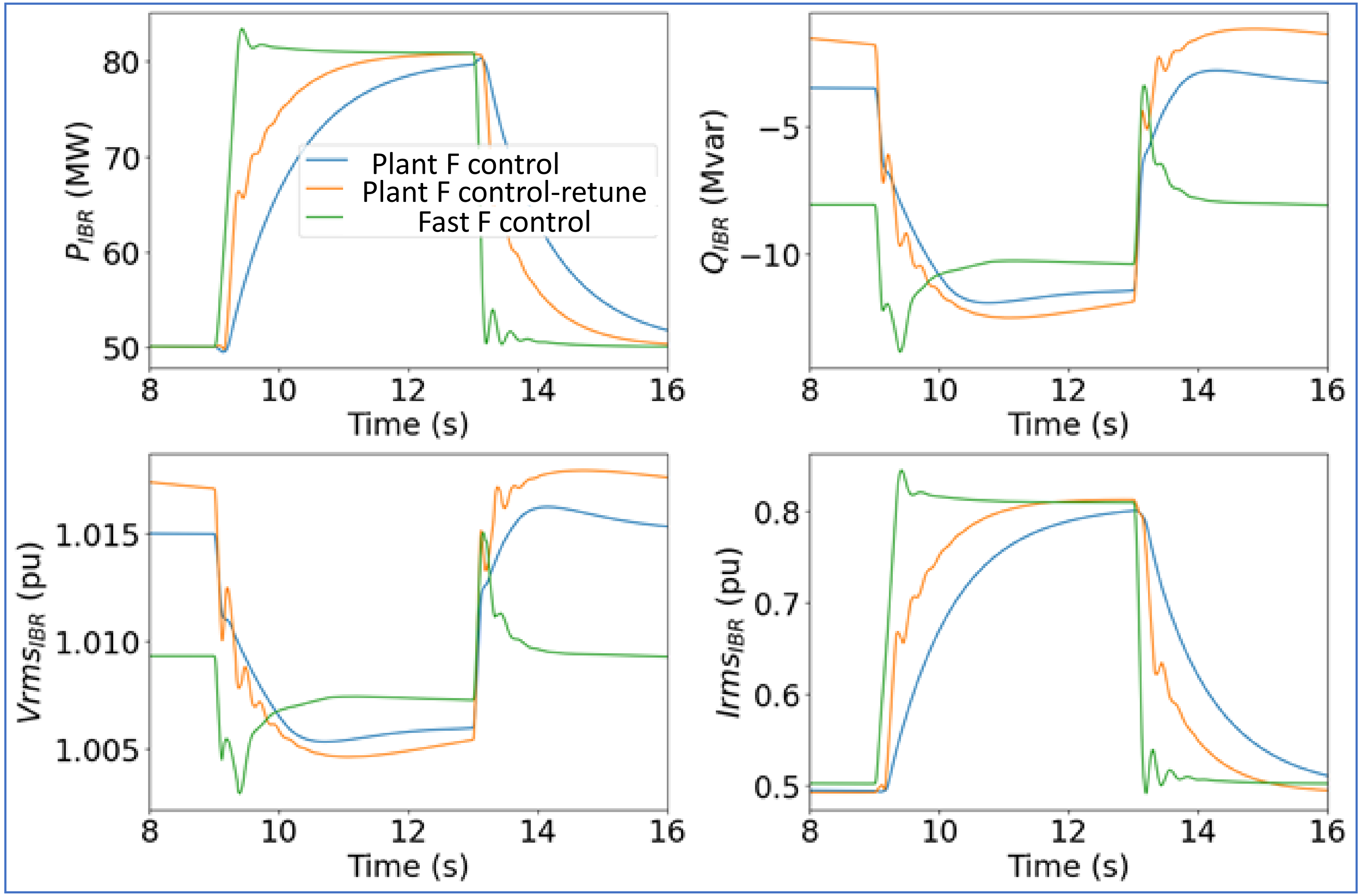
Terminal V control



- Plant level voltage control can be augmented with inverter level voltage control
- Could provide improved benefit with high IBR systems

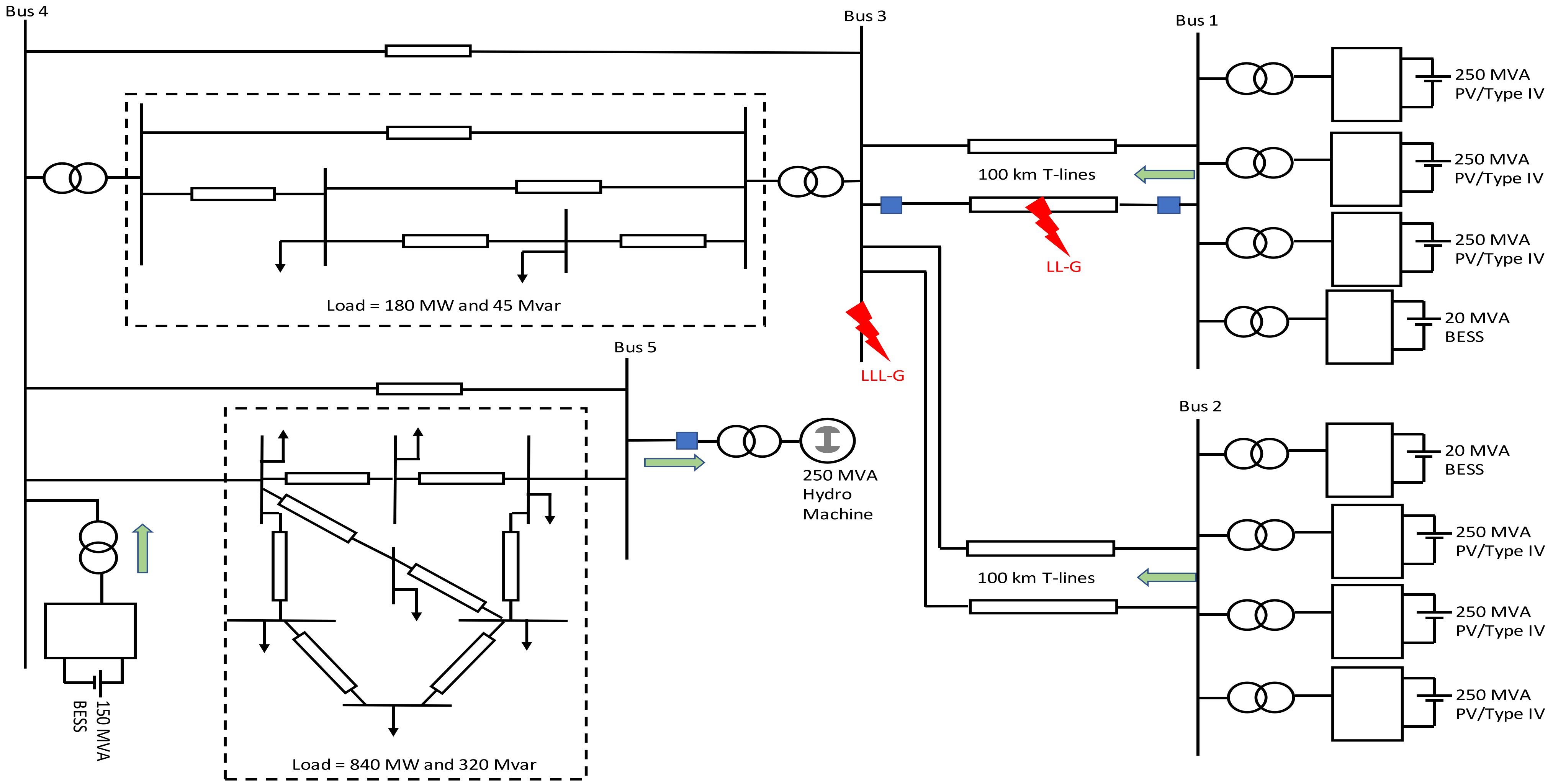
Bringing about fast frequency response at device level

Fast frequency control



- Plant level frequency control can be augmented with inverter level fast frequency control
- Could provide improved benefit with high IBR systems

Impact of improved voltage and frequency support from BESS

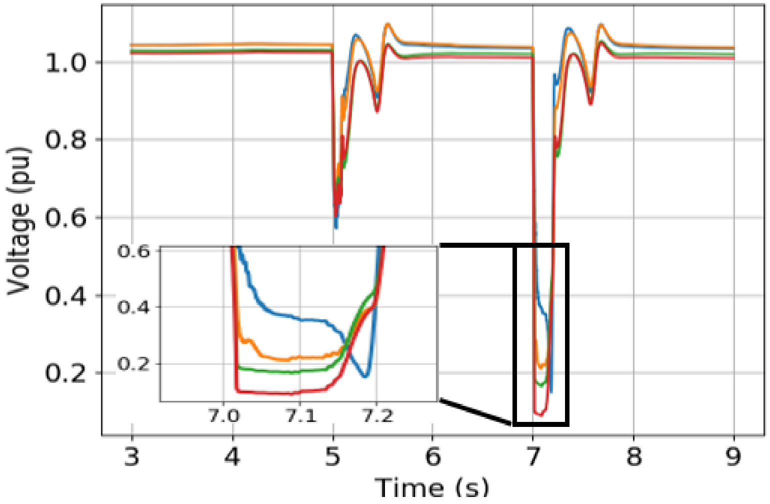


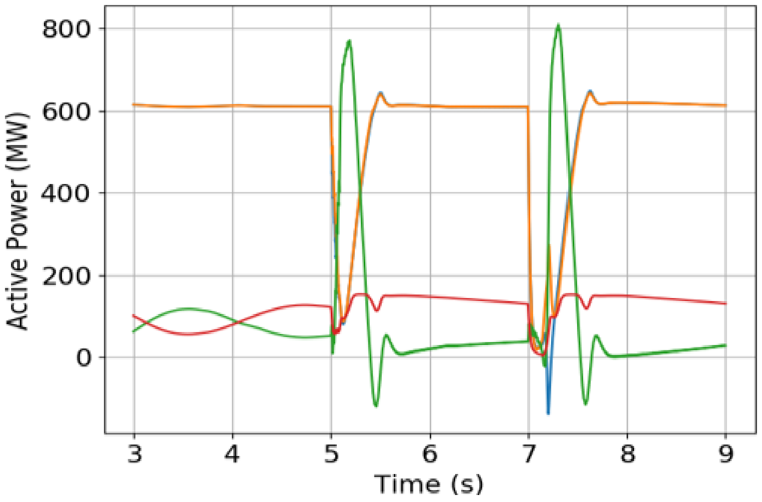
Non-BESS IBR provide slower voltage response and no frequency response

BESS provides both fast voltage and frequency response

Response to different type of events…

LL-G fault at 5.0s followed by LLL-G fault at 7.0s

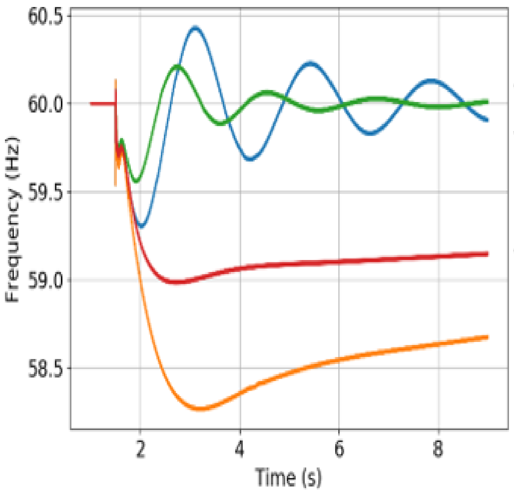


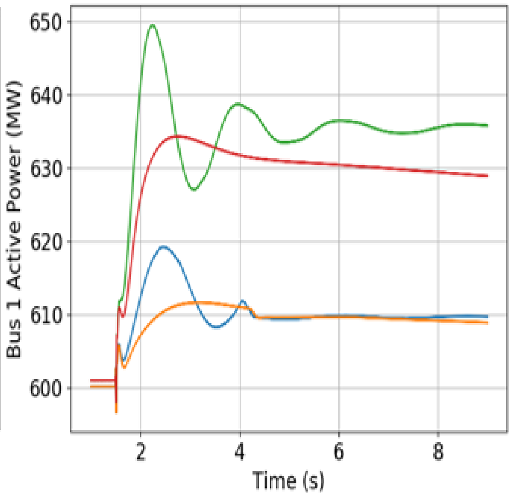


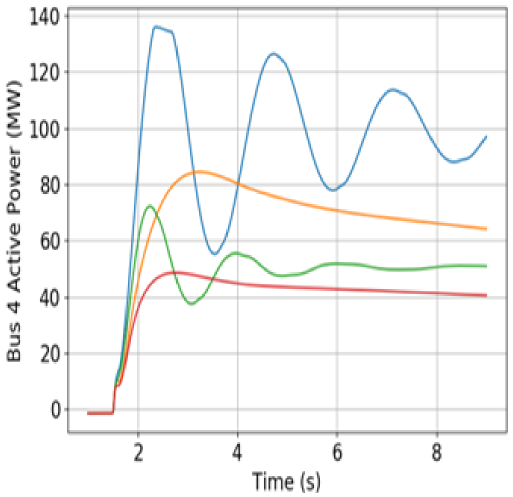
legend: Bus 1, Bus 2, Bus 5, Bus 4

- Robust fault ride through behavior
- Potential edge case that could trigger voltage collapse

10% increase in load at 1.5s

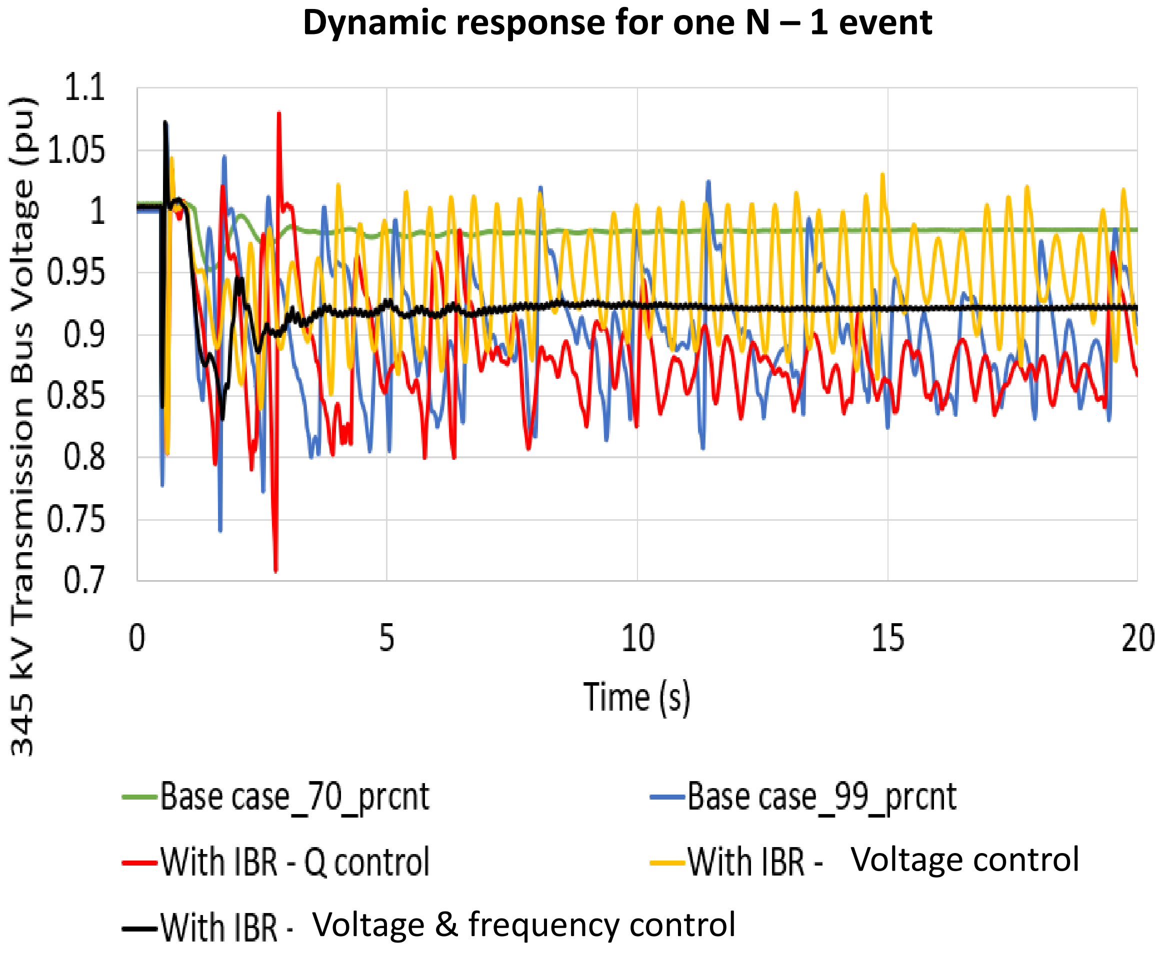


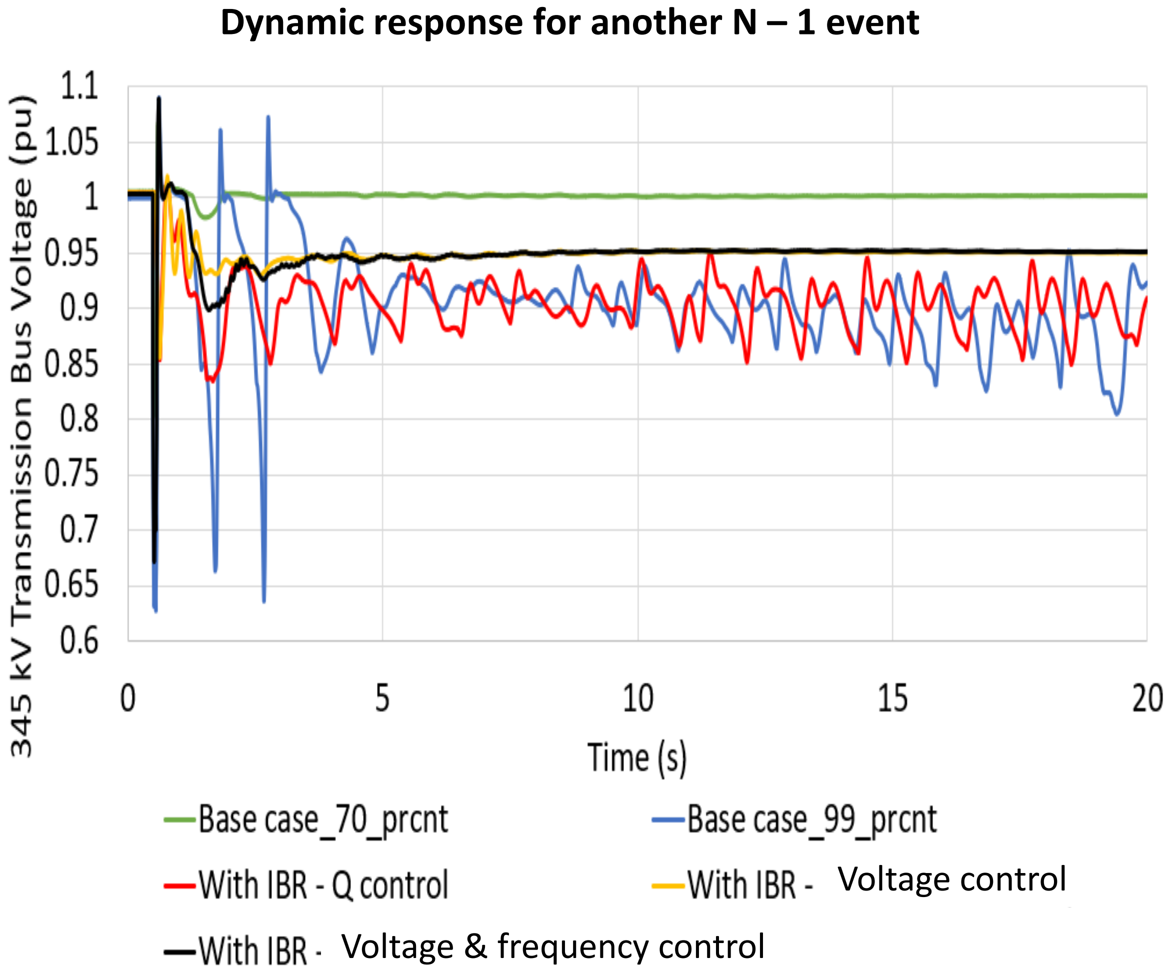




- BESS can provide fast frequency response in addition to voltage control to provide superior frequency response
- Only 10 kWh increase in energy injection

Potential application in South Texas to increase export of wind





With the inclusion of BESS with fast voltage and frequency control, wind export could be increased by 1 GW

How would this extend to 100% IBR and/or weak areas?

IBRs in future 100% scenario

Recap of terminology

Legacy IBR

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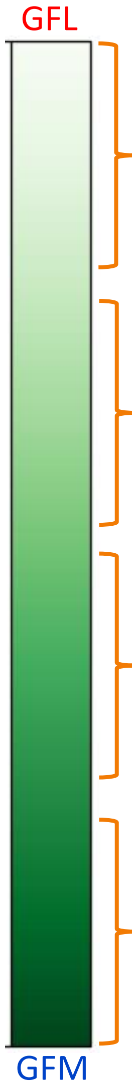


Most power networks are at this position

Few power networks use this capability

Very few power networks ask and use this capability

Not in use (apart from few small islands); Area of active research

What is grid forming (GFM)?

Grid following (GFL) vs Grid forming (GFM) control

Time scale	Grid Following (GFL)	Grid Forming (GFM)
Sub-transient	Constant output current for P/Q control	Constant output voltage for V/f control
Transient	Active and reactive power control	Voltage and frequency control
Steady – state	May follow the same droop characteristics	

Grid-following (GFL) Controls

- Maintain a constant output current phasor to control the active and reactive power injected by the IBR into the network in the sub-transient to transient time frame.
- They are inherently dependent on grid-strength and cannot operate in islanded mode or provide black-start capabilities.

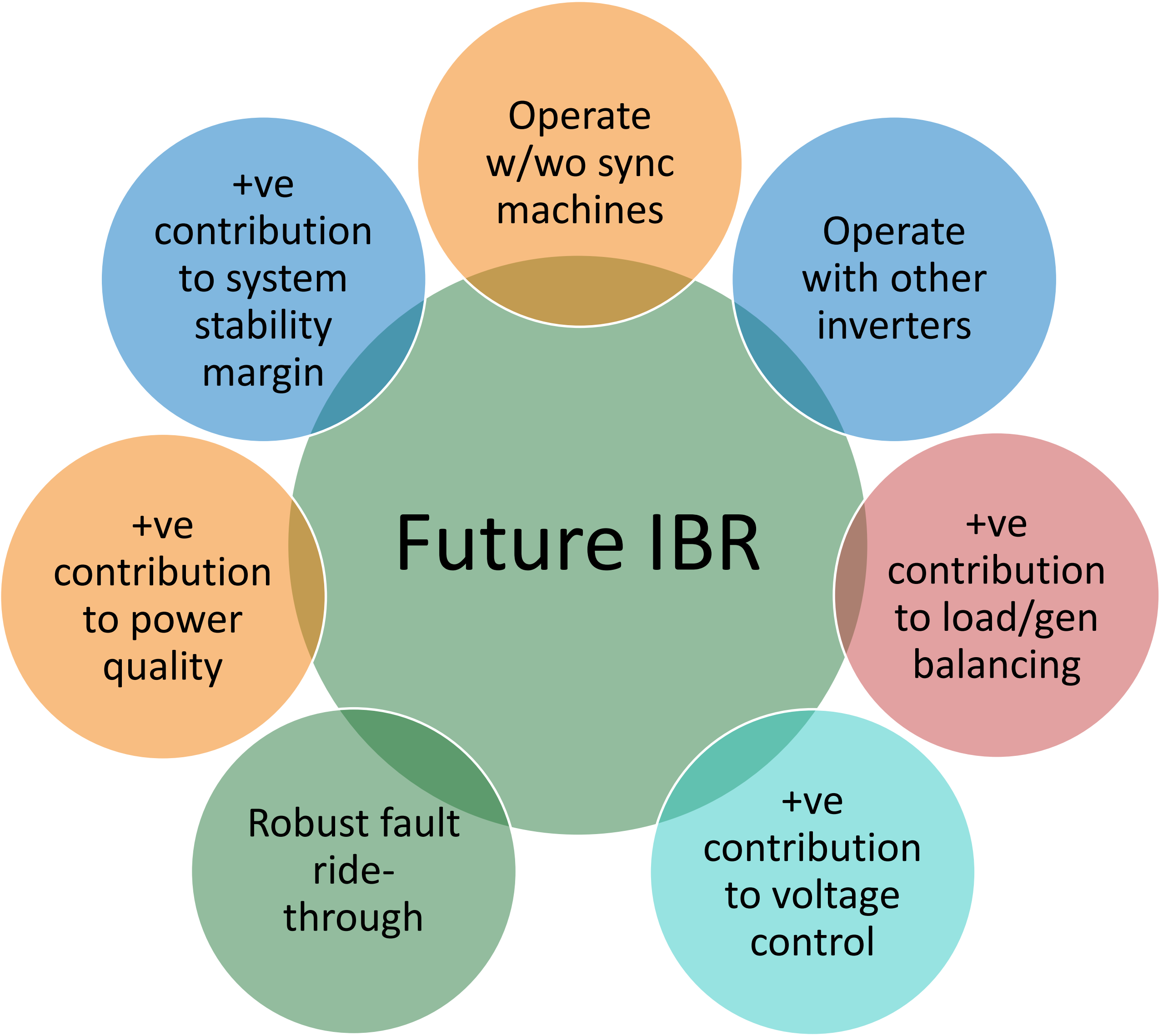
VS.

Grid-forming (GFM) Controls

- Maintain a constant internal voltage phasor & frequency, which is controlled to maintain synchronism with other devices and to regulate IBR active and reactive power in the sub-transient to transient time frame.
- Can provide black start and continue operation even in the absence of synchronous generators.

https://sites.google.com/view/unifi-consortium/publications

Performance requirement for future IBR



- Future inverter can be defined based on its capability and the grid services it provides
- These services should be provided while *meeting standard acceptable metrics* associated with reliability, security, and stability of the power system and *within equipment limits*
- *Few IBRs* can also be designated as blackstart resources

BESS as a potential future IBR providing services

- Providing fast and stable response to the bulk power system in milli-seconds time frame, can require stiff dc bus

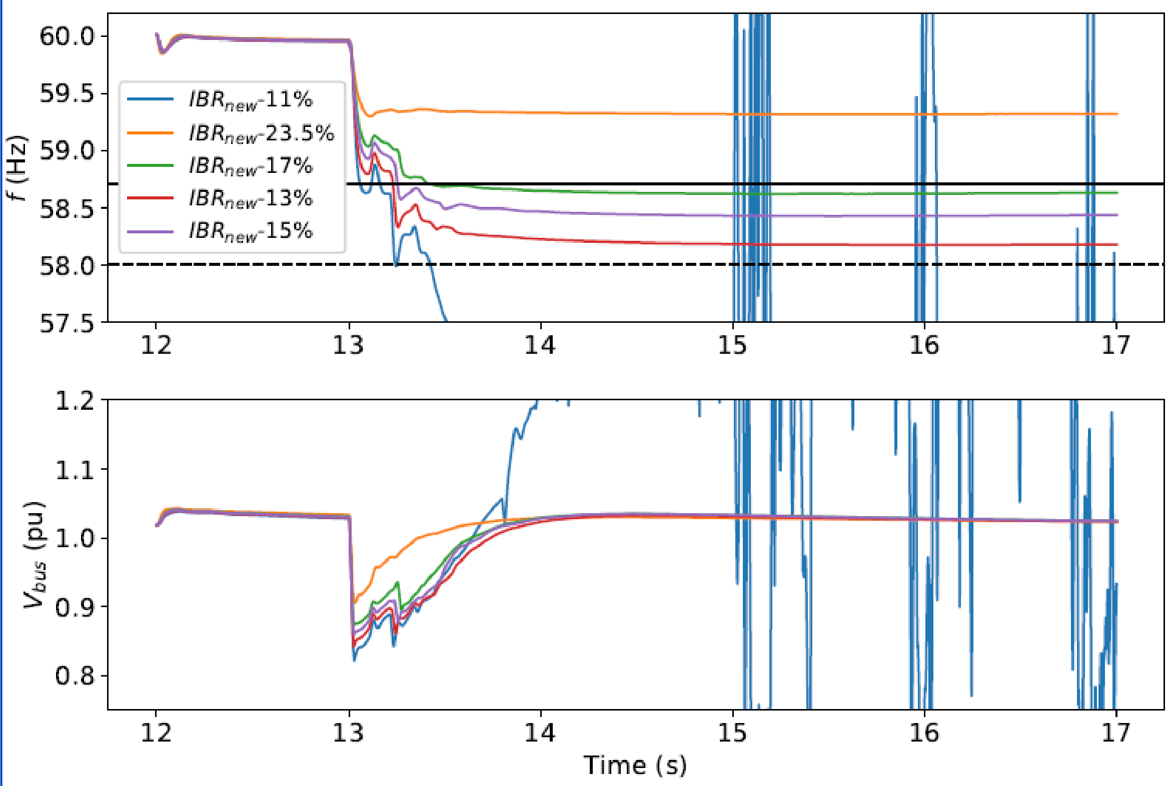
- While it is possible to achieve this with strong dc voltage control in non-BESS IBRs, the interactions between this control and ac side control is not fully known yet.

Few example scenarios of use of BESS

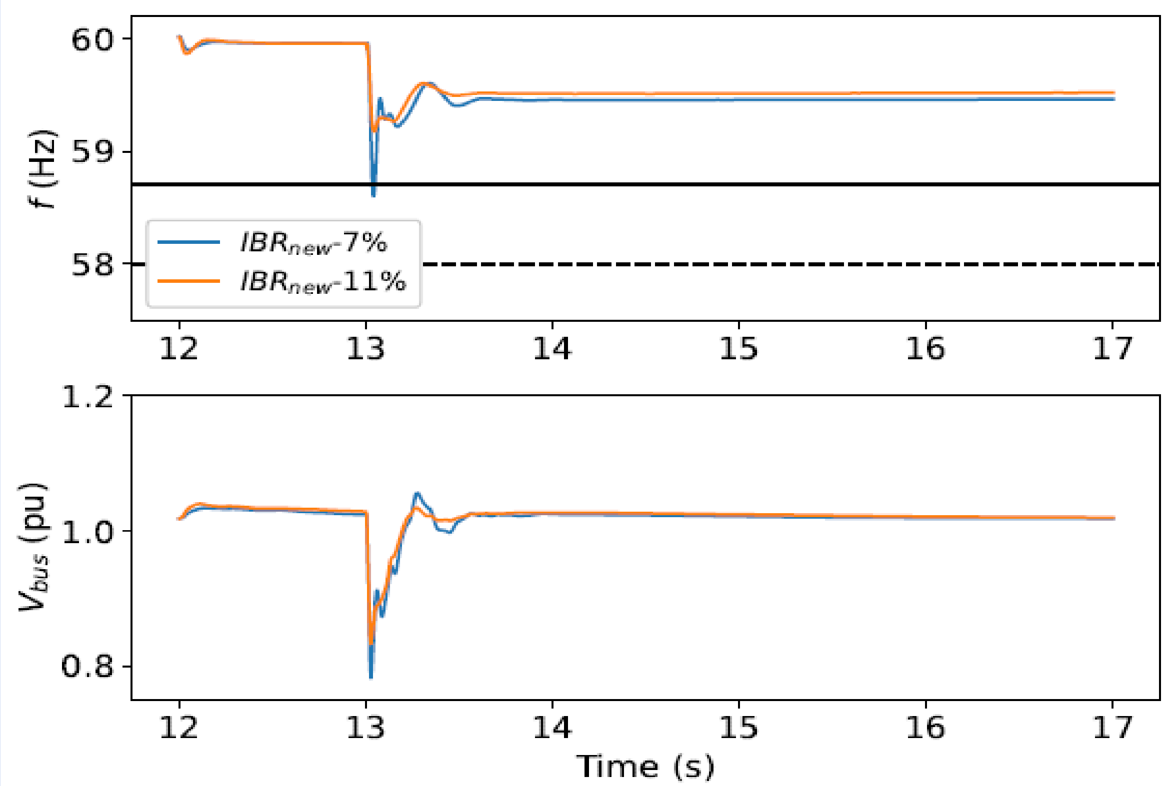
Island network

Objective: Evaluate percentage of new future IBR required for the future network to avoid trigger of UFLS

When existing IBRs provide no frequency or voltage support



When existing IBRs provide fast frequency and voltage response



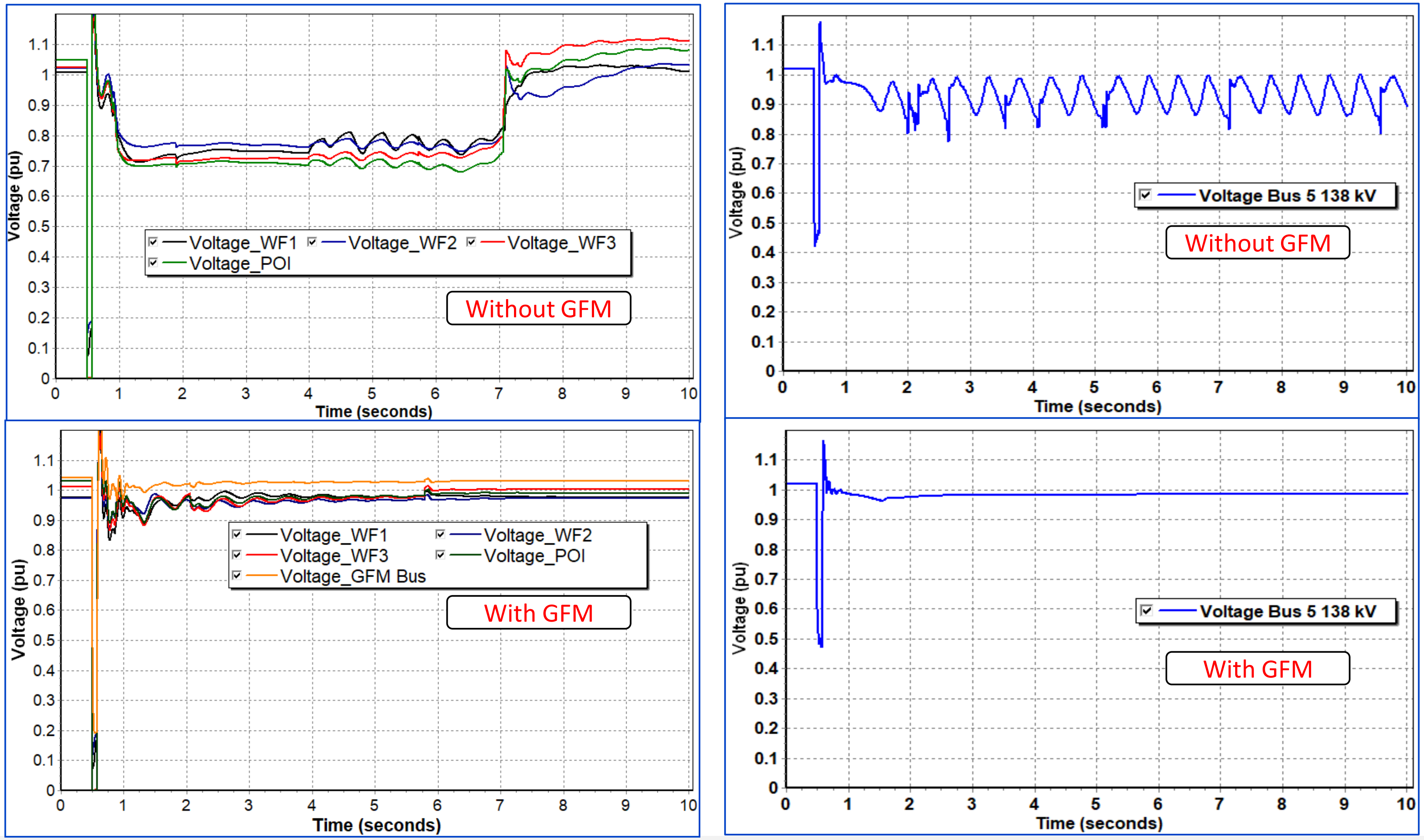
Obtaining a definite percentage of required future IBR needs to take into consideration performance of other devices in the network

Southwest region of North America

Objective: Evaluate ability of future BESS to stabilize local areas with high IBR generation under N-x contingency

Local area 1

Local area 2



- Adding BESS to the local areas has capability to improve stability and increase transfer from IBR.
- Sizing and siting of resource is important

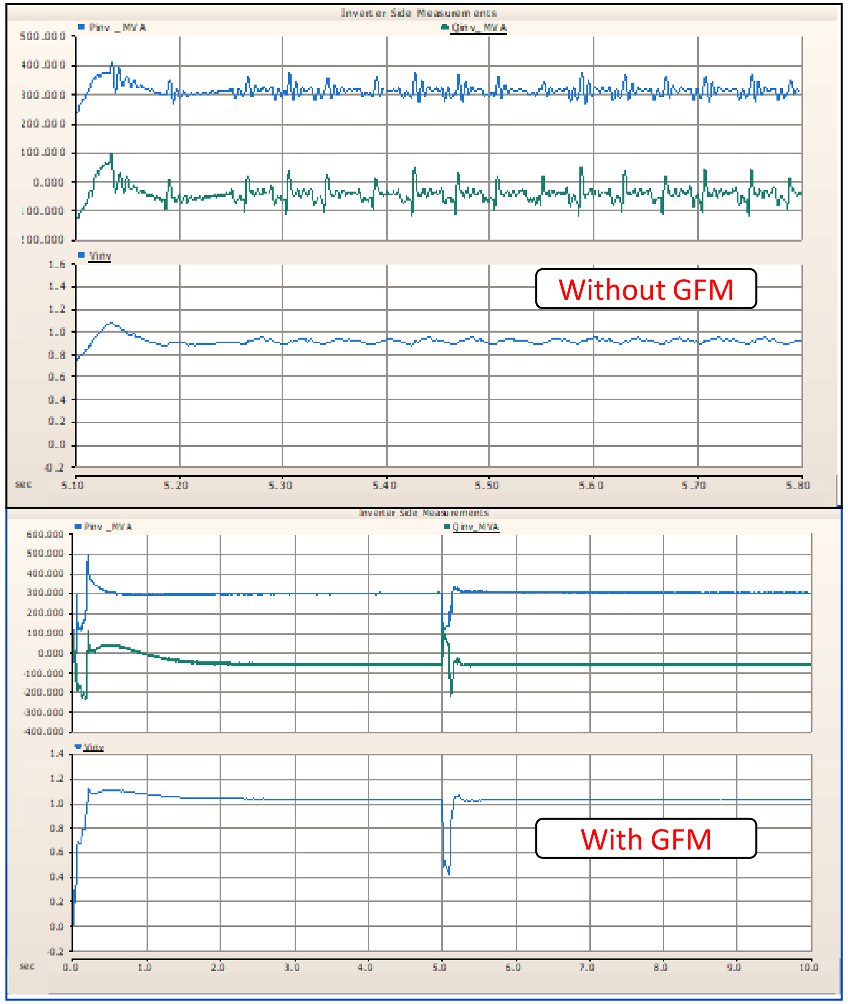
BESS can be a solution (out of many) to help stability and increase power transfer from IBRs

Southeast region of North America

Objective: Evaluate ability of BESS to stabilize local areas with high IBR generation under N-*x* contingency

Local area 1

Local area 2

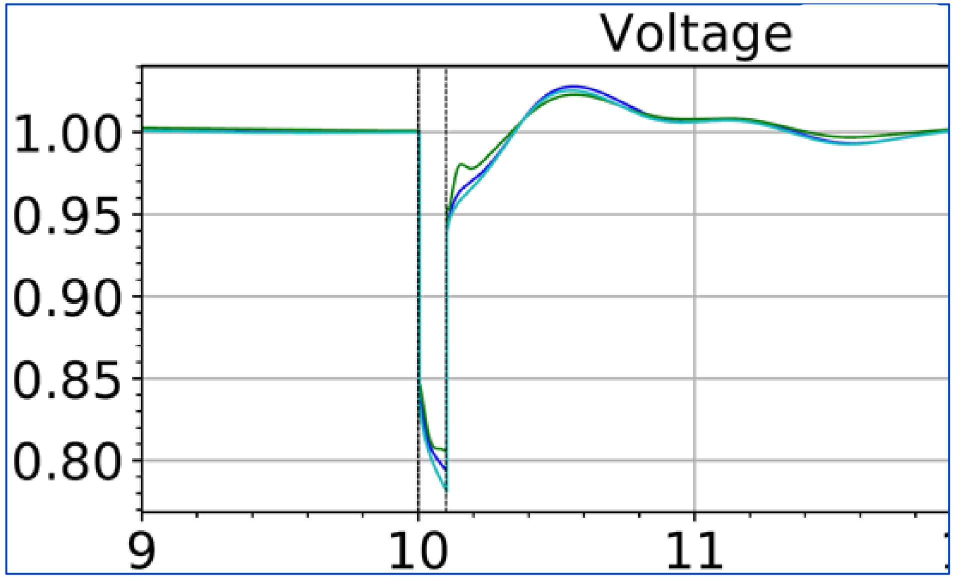


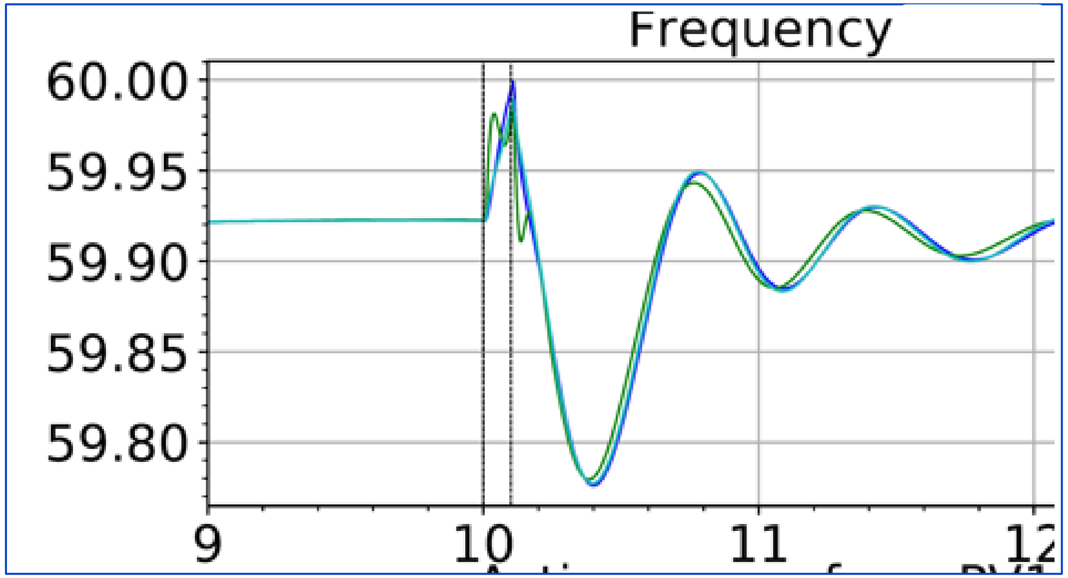
- Adding BESS to the local areas has capability to improve stability and increase transfer from IBR.
- Sizing and siting of resource is important

BESS can be a solution (out of many) to help stability and increase power transfer from IBRs

Midwest region of North America

Objective: Evaluate need of BESS for a new IBR installation that is replacing synchronous generation





IBR as GFL in blue curves

IBR as GFM in green curves

IBR as GFL with SynCon in turquoise curves

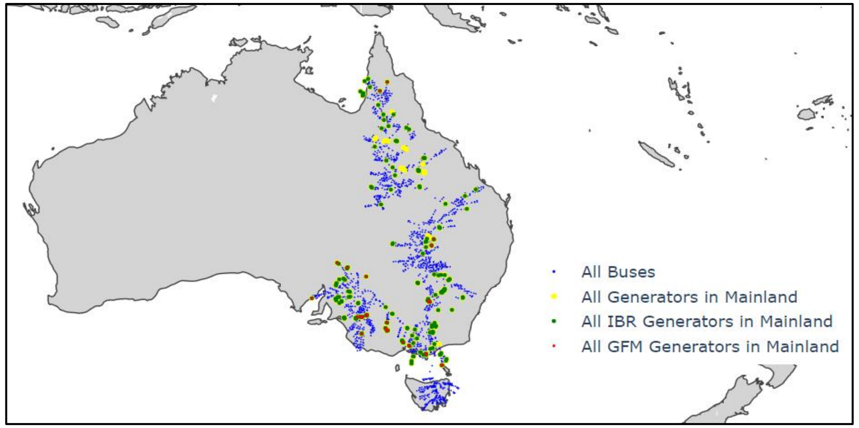
- System region weakened to represent a potential future scenario
- A variety of N-*x* contingency events studied
- At this location on the network, need for GFM at this point in time may not provide additional advantage

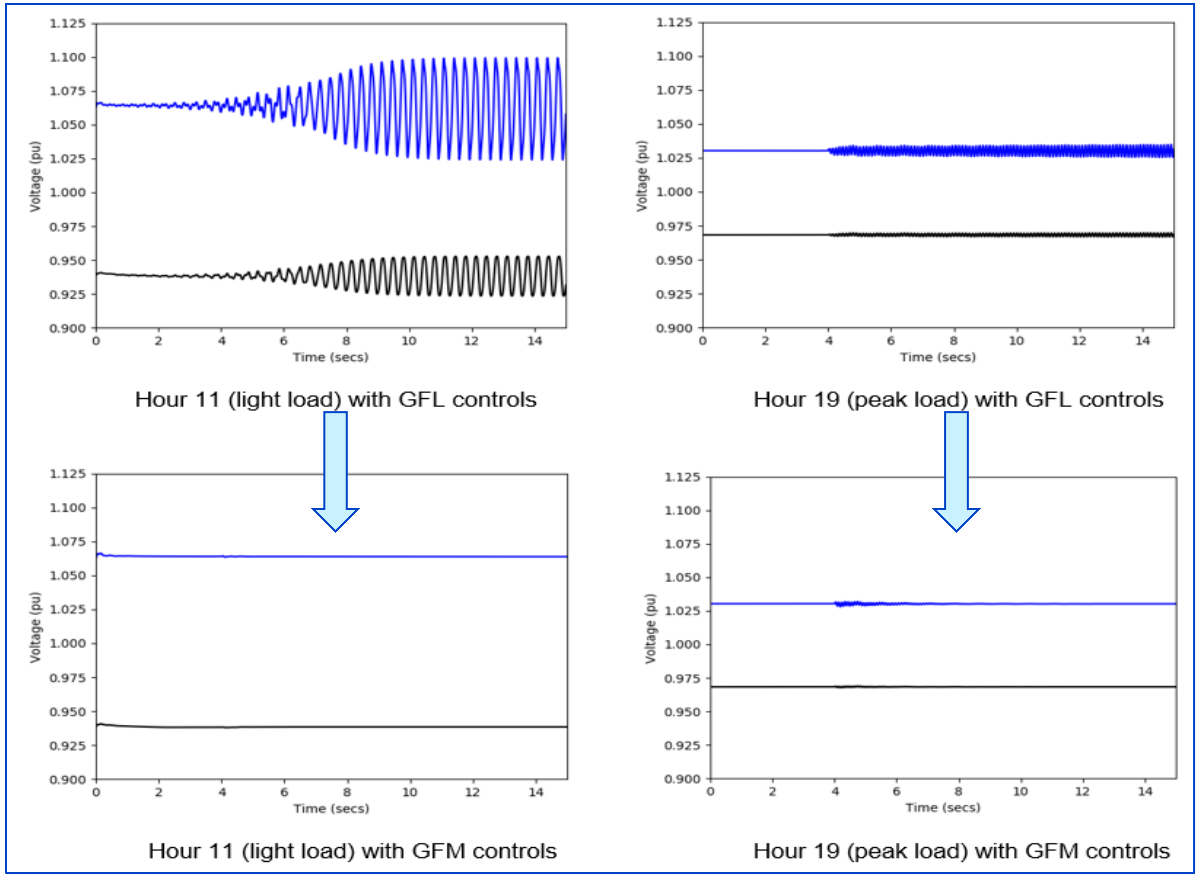
In a large interconnected system, not all resources need to provide all grid services

Long interconnected power system

Objective: Determine size, location, and impact of BESS on small signal stability across 24 hours with high IBR percentage

Remaining MVA





Since case study results may be classified as CEII, a synthetic Australia network used to show visualization of results

Use of GFM devices at identified locations can help mitigate small signal instability across a 24-hour period

Summary

Takeaways

- Maintaining reliability in the power network is a team sport
  - If each device (player) contributes a bit, the benefits can be tremendous
- Increased utilization of fast inverter level voltage and frequency control can improve reliability
  - A lot of capability from IBRs is being left under utilized
  - BESS provides stiff dc buses that can be leveraged for such fast services
- BESS as resource could also provide blackstart/restoration services
  - A topic for another discussion
- It is understood that delivery of service from BESS may have economic implications, but the topic is outside scope of technical capability

Together...Shaping the Future of Energy®

NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Battery Energy Storage

NERC Technical Subcommittee Analysis

JP Skeath, Senior Engineer

NPCC DER Forum

October 12, 2023

RELIABILITY | RESILIENCE | SECURITY

BPS-Connected Inverter Based Resources (IBRs)

Inverter-based Resource Performance Subcommittee (IRPS)

NERC IBR Strategy

Risk Analysis	Interconnection Process Improvements	Best Practices and Education	Regulatory Enhancements
Event Analysis	Improvements to GIAs and GIP	Reliability Guidelines	NERC Standards Projects
Disturbance Reports	Enhanced Interconnection Requirements	Webinars and Workshops	BES Definition Review
Alerts	Modeling and Study Improvements	Outreach and Engagement	Inverter-Specific Requirements and Standards
Lessons Learned	IEEE 2800-2022	Emerging Reliability Risk Issues	Risk-Based Compliance

NERC IBR Strategy

IBR Quick Reference Guide

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Quick Reference Guide: Inverter-Based Resource Activities

March 2023

INSIDE THIS QUICK REFERENCE GUIDE

IBR Strategy | Disturbance Reports | Alerts | Reliability Guidelines | White Papers |
Technical Reports | Standards Activities | Other Activities | Stakeholder Groups

The electric power grid in North America is undergoing a significant transformation in technology, design, control, planning, and operation, and these changes are occurring more rapidly than ever before. Particularly, technological advances in inverter-based resources are having a major impact on generation, transmission, and distribution systems.

In most cases, inverter-based generating resources refer to Type 3 and Type 4 wind power plants and solar photovoltaic (PV) resources. Battery energy storage is also considered an inverter-based resource. Many transmission-connected reactive devices, such as STATCOMs and SVCs, are also inverter-based. Similarly, HVDC circuits also interface with the ac network though converters. Inverter-based resources are being interconnected at the bulk power system (BPS) level as well as at the distribution level; however, this reference guide focuses specifically on BPS-connected inverter-based resource efforts.

This document acts as a quick reference guide for the work that the ERO Enterprise has done regarding inverter-based resource activities over the past seven years to ensure the continued reliability of the North American power grid.

RELIABILITY | RESILIENCE | SECURITY

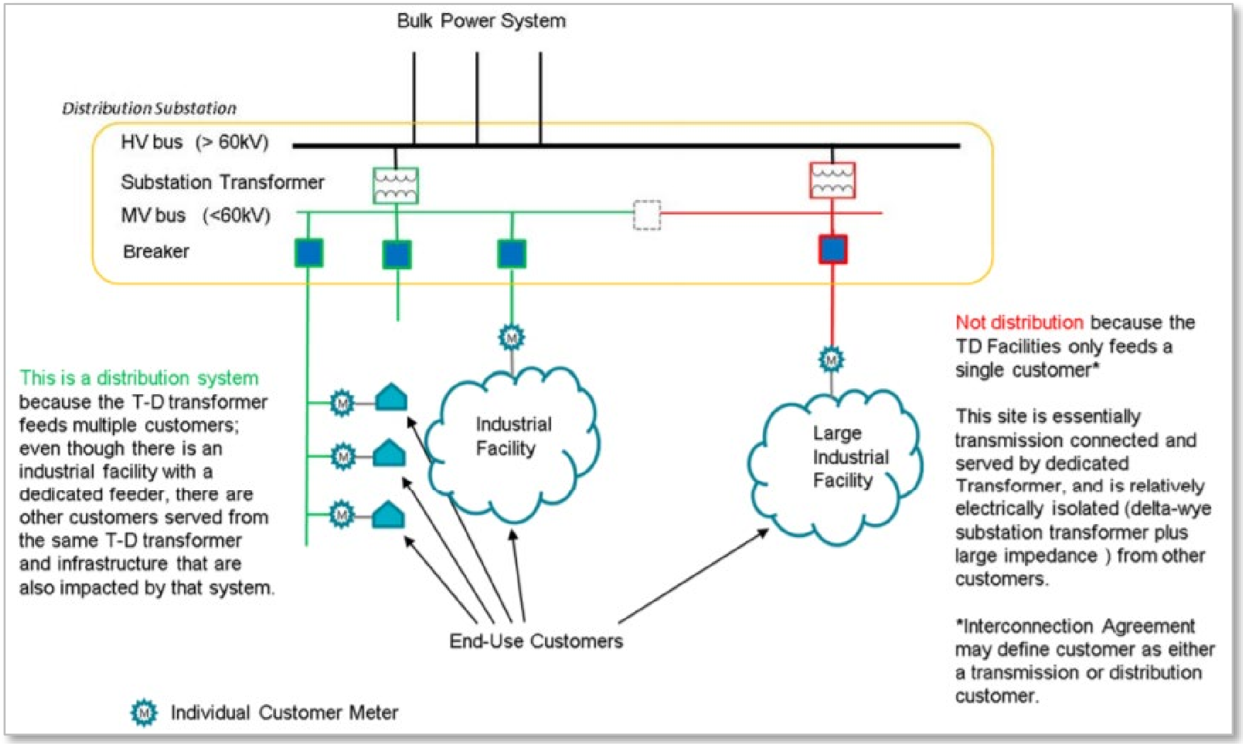
IBR Quick Reference Guide

Aggregate Impacts of Distribution-Connected Energy Resources

NERC System Planning Impacts of Distributed Energy Resources Working Group (SPIDERWG)

SPIDERWG Working Definition of DER

- **DER:** Any source of electric power located on the distribution system.



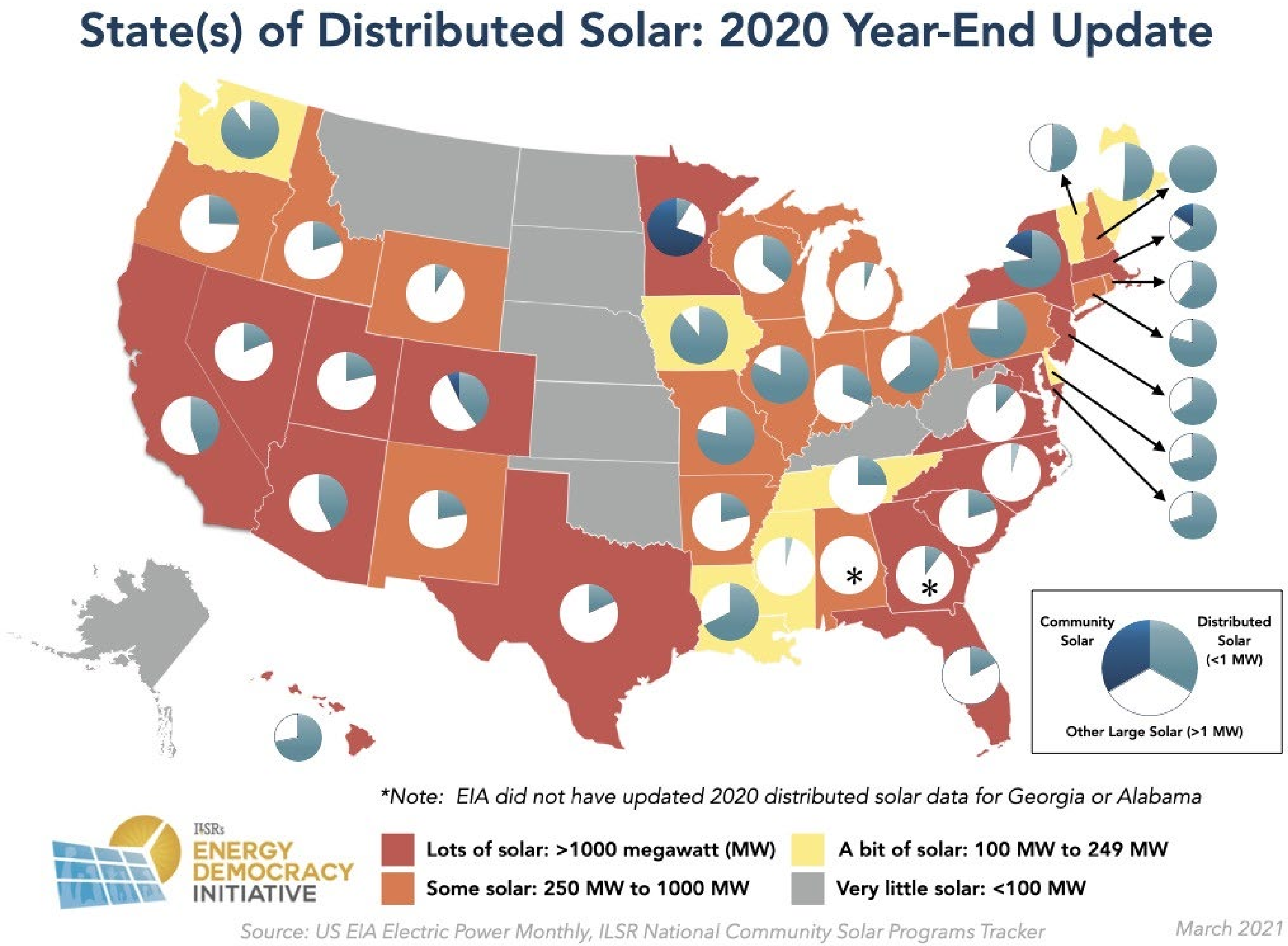
Distributed Demand Modifying Resource

Distributed Energy Resources + **Load Modifiers**

Distributed Energy Resources:
- Distributed Generation
- Energy storage
  - (including bi-directional EVs)

Load Modifiers:
- Demand response
- Time of use rate impacts
- Managed EV charging
- Energy efficiency
- CVR or Cap banks? (VARs?)

Distributed Solar



https://ilsr.org/the-states-of-distributed-solar/

DERs

shutterstock.com · 1750483022

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Not DERs

NERC DER Strategy

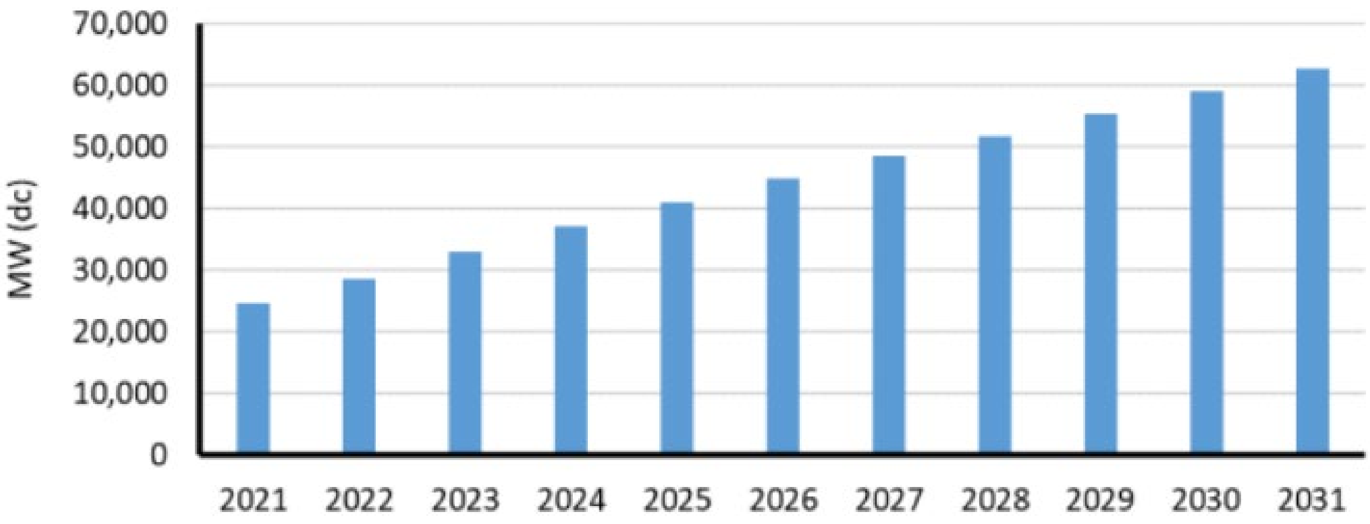


Figure 1: Cumulative Distributed Solar Photovoltaic Capacity[3]

https://www.nerc.com/comm/RSTC/Documents/NERC_DER%20Strategy_2022.pdf

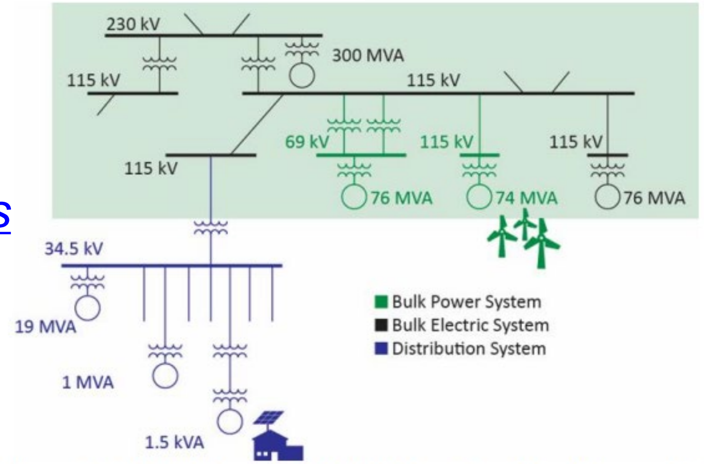


Figure 2: BES, BPS, and Distribution Graphical Examples[4]

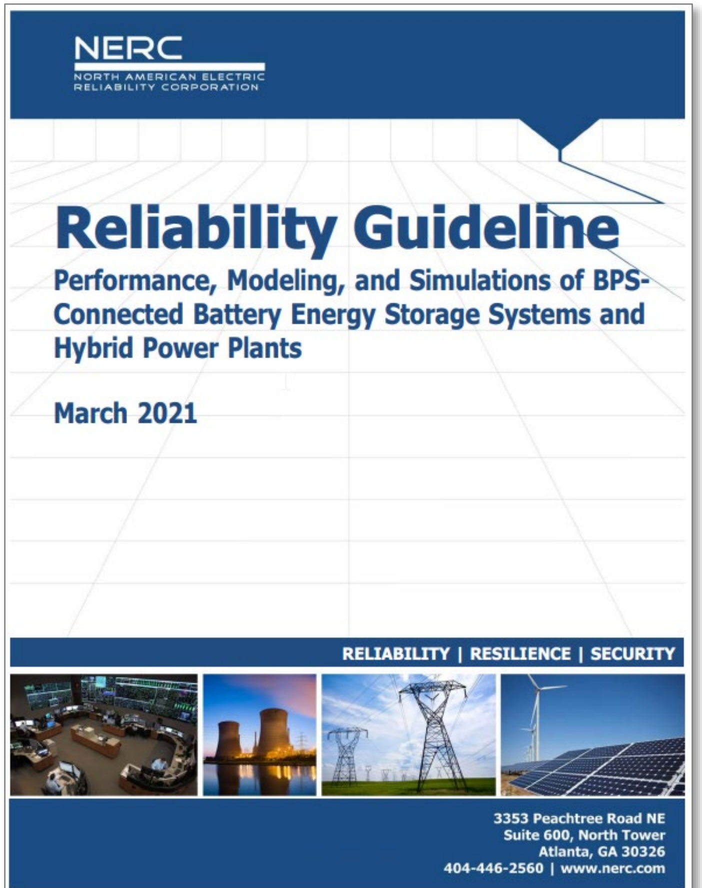
NERC DER Strategy

DER Modeling	Studies Incorporating DER	Operational Impacts of DER	Regulatory Considerations
Data Collection	Planning Studies	T-D Impacts	Aggregator
Modeling Tools	Design Criteria	Aggregator	NERC Standards Enhancements
Verification	Operations Planning	Protection Systems	Cybersecurity
Modeling Usage		Decentralization	Training

Strong Foundation of Coordination between
Regulatory Agencies: FERC, NARUC, CER
Industry Stakeholders: SPIDERWG, RSTC, SC, NATF, EEI, ESIG
Ongoing Research and Design: EPRI, National Labs, Academia

Work on Battery Energy Storage

IRPS



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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability Guideline

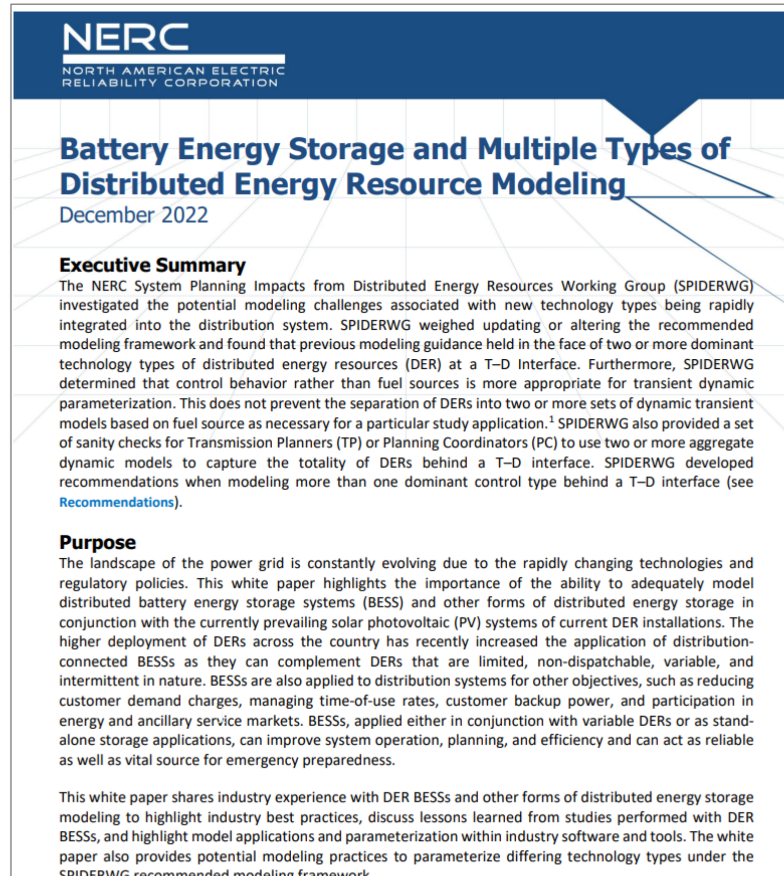
Performance, Modeling, and Simulations of BPS-Connected Battery Energy Storage Systems and Hybrid Power Plants

March 2021

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

SPIDERWG



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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Battery Energy Storage and Multiple Types of Distributed Energy Resource Modeling

December 2022

Executive Summary

The NERC System Planning Impacts from Distributed Energy Resources Working Group (SPIDERWG) investigated the potential modeling challenges associated with new technology types being rapidly integrated into the distribution system. SPIDERWG weighed updating or altering the recommended modeling framework and found that previous modeling guidance held in the face of two or more dominant technology types of distributed energy resources (DER) at a T–D Interface. Furthermore, SPIDERWG determined that control behavior rather than fuel sources is more appropriate for transient dynamic parameterization. This does not prevent the separation of DERs into two or more sets of dynamic transient models based on fuel source as necessary for a particular study application.[1] SPIDERWG also provided a set of sanity checks for Transmission Planners (TP) or Planning Coordinators (PC) to use two or more aggregate dynamic models to capture the totality of DERs behind a T–D interface. SPIDERWG developed recommendations when modeling more than one dominant control type behind a T–D interface (see Recommendations).

Purpose

The landscape of the power grid is constantly evolving due to the rapidly changing technologies and regulatory policies. This white paper highlights the importance of the ability to adequately model distributed battery energy storage systems (BESS) and other forms of distributed energy storage in conjunction with the currently prevailing solar photovoltaic (PV) systems of current DER installations. The higher deployment of DERs across the country has recently increased the application of distribution-connected BESSs as they can complement DERs that are limited, non-dispatchable, variable, and intermittent in nature. BESSs are also applied to distribution systems for other objectives, such as reducing customer demand charges, managing time-of-use rates, customer backup power, and participation in energy and ancillary service markets. BESSs, applied either in conjunction with variable DERs or as stand-alone storage applications, can improve system operation, planning, and efficiency and can act as reliable as well as vital source for emergency preparedness.

This white paper shares industry experience with DER BESSs and other forms of distributed energy storage modeling to highlight industry best practices, discuss lessons learned from studies performed with DER BESSs, and highlight model applications and parameterization within industry software and tools. The white paper also provides potential modeling practices to parameterize differing technology types under the SPIDERWG recommended modeling framework.

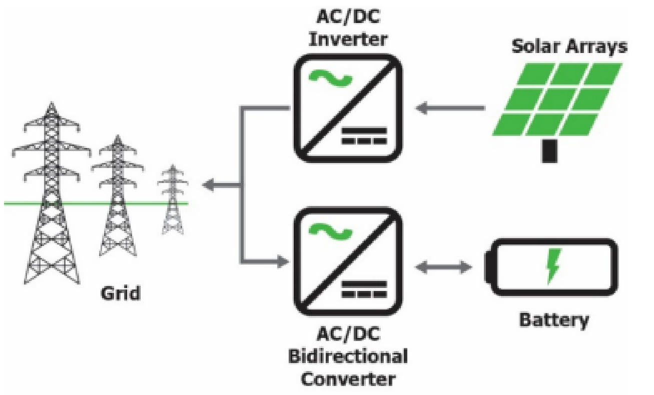


Figure I.1: Illustration of AC-Coupled Hybrid Plant

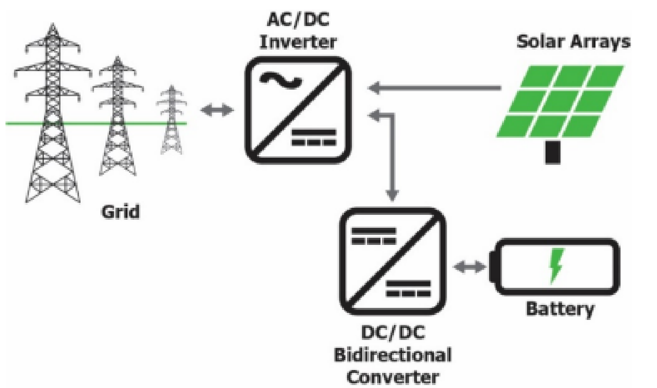
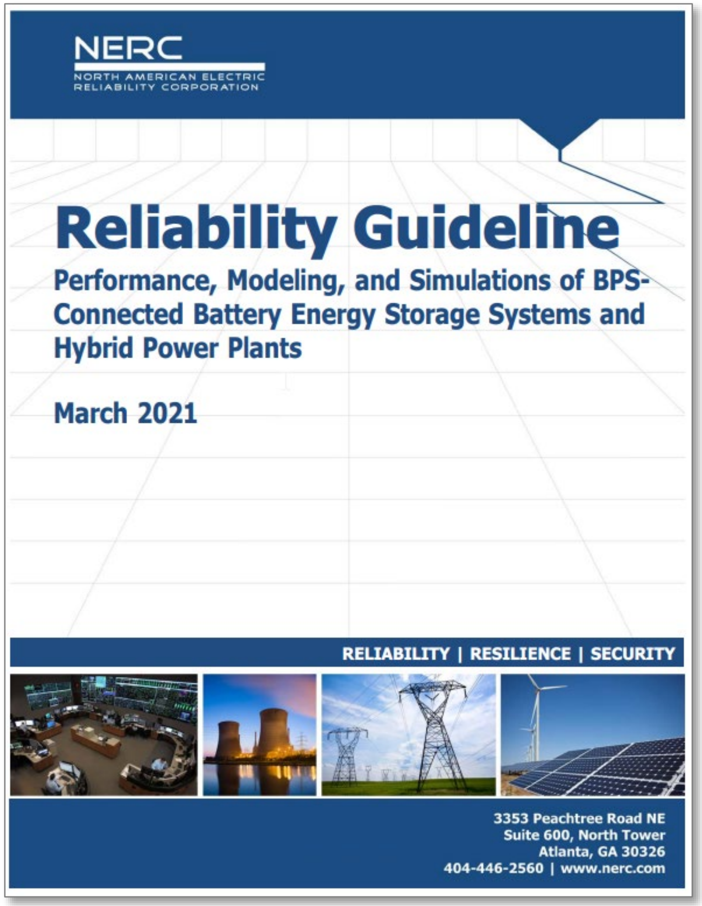


Figure I.2: Illustration of DC-Coupled Hybrid Plant

IRPS Guideline

IRPS – Bulk-connected Resources

- BESS comes in two forms:
  - Standalone battery
  - Hybrid connected Battery and other resource (RG focus)
- Interconnection procedures should be clear
- Models should match as-build controls, settings, performance
- Software Enhancements and model enhancements (UDM)
- Study Expansion



IRPS – Bulk-connected Resources

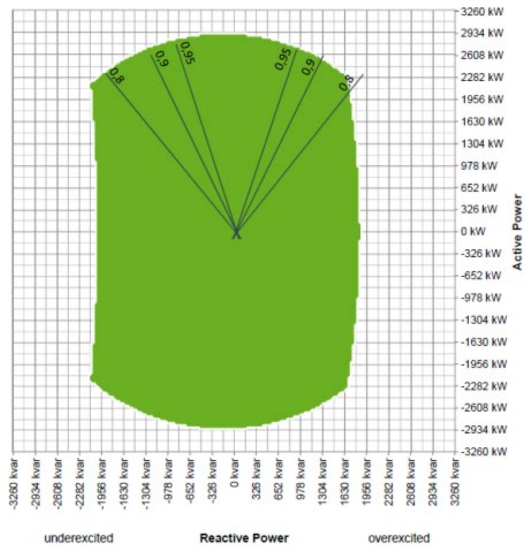


Figure 1.1: Example of 2.7 MVA BESS Capability Curve [Source: SMA America]

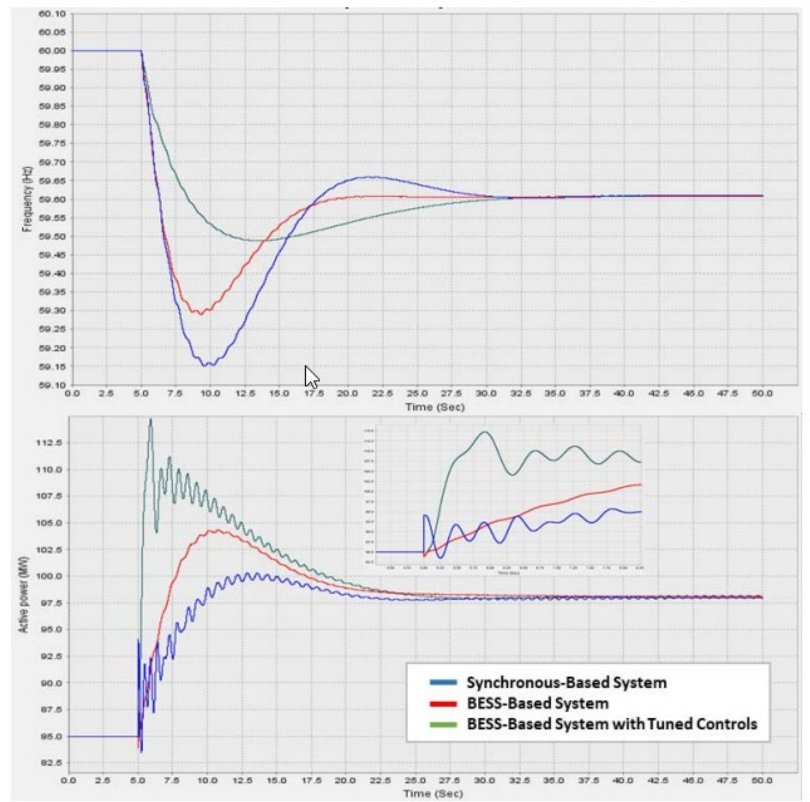


Figure 1.2: Demonstration of Impacts of a BESS on Frequency Response [Source: EPRI]

IRPS – Bulk-connected Resources

Lumped

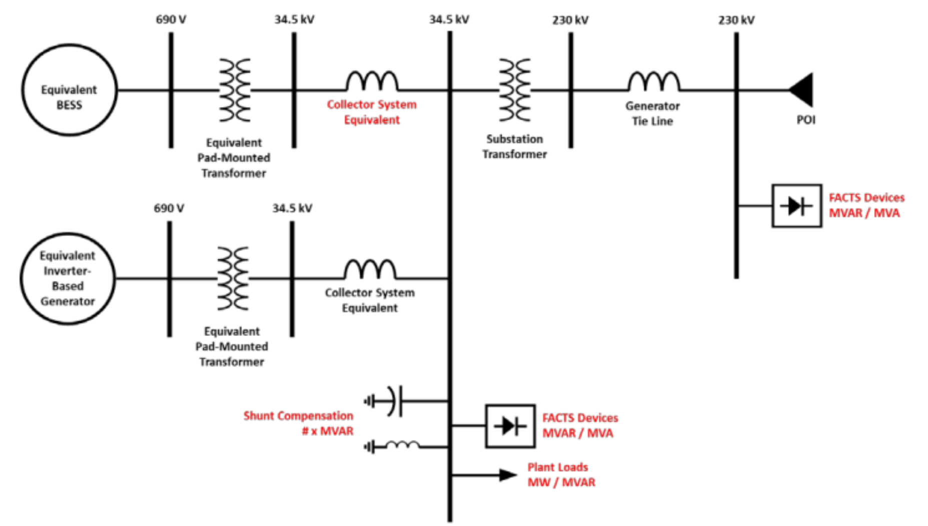


Figure 2.2: Generic Power Flow Model Example for AC-Coupled Hybrid Power Plants

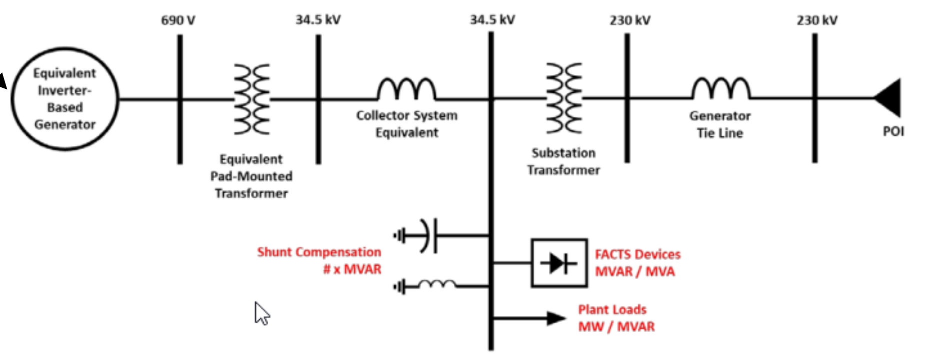


Figure 2.3: Generic Power Flow Model for DC-Coupled Hybrid Power Plants

Study Differences for Add-On BESS

Table 5.2: Interconnection Study Needs for Battery Storage Addition at Existing Plant			
Process/ Study	**AC-Coupled or DC-Coupled with New/Modified Inverter**	**DC-Coupled with Existing Inverter and Grid Charging**	**DC-Coupled without Grid Charging (no inverter changes)**
Registration with and Notification to the TP/PC	Needed	Needed	Needed
Steady-State Power Flow Study	Needed if the maximum plant active power injection or withdrawal capability changes or if the operational characteristics change; not needed otherwise	Needed to study charging mode	May be needed to study different operating conditions
Short-Circuit Study	Needed	Not needed	Not needed
Stability Study[88]	Needed	Needed to study charging mode	May be needed to study different operating conditions

SPIDERWG Whitepaper

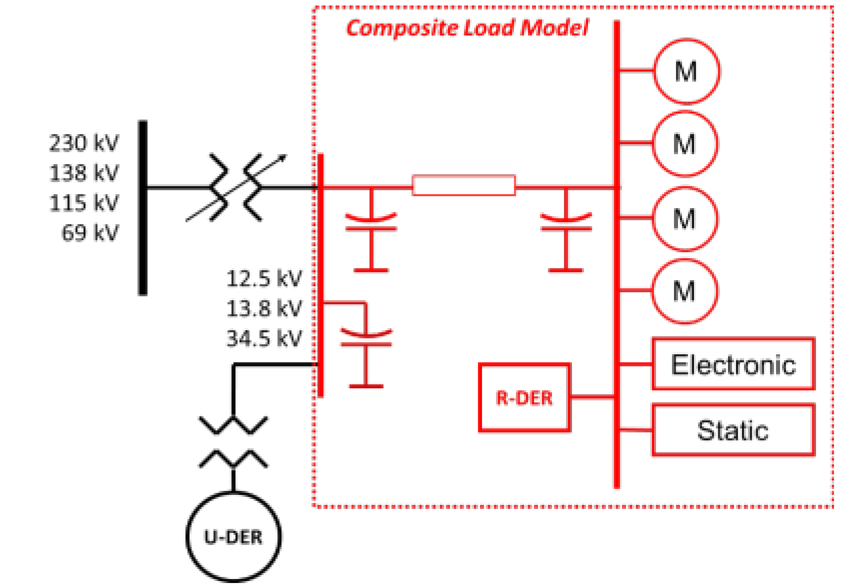
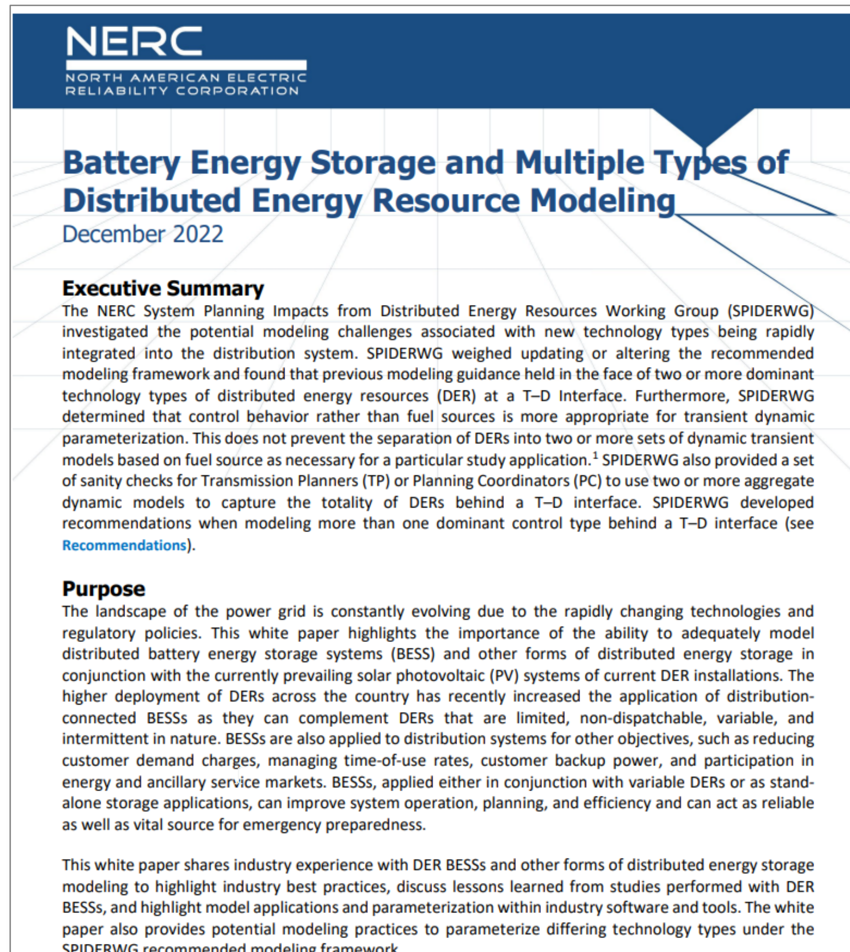


Figure 1: Recommended DER Modeling Framework

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

SPIDERWG – Distributed Energy Resources

- No Change to modeling framework to account for BESSs
- Case assumption alignment
- Separation of aggregation where needed
- Focus on voltage and frequency control shifts over resource type
- Aggregate SOC not useful in stability



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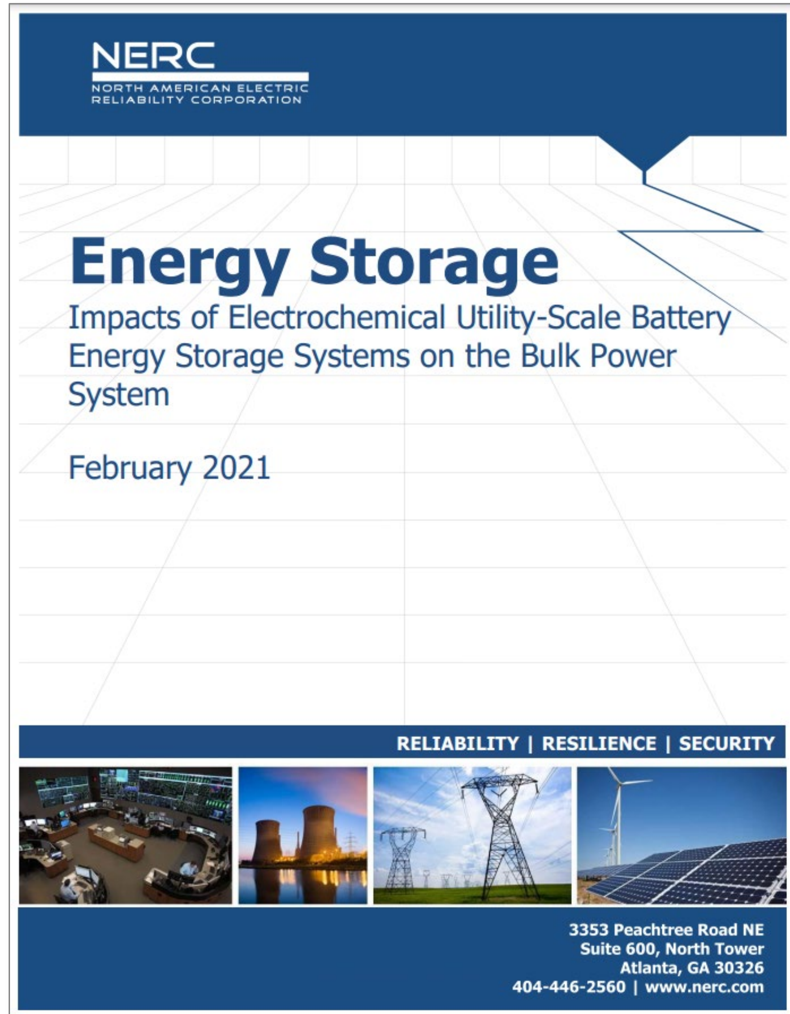
NERC's Electric Storage Report

NERC ESAT Report

- BESS were projected to grow at an increasing pace
- BESS can mitigate frequency excursions and UFLS events
- Modeling and Reporting revisions necessary
- NERC standards reflect as an IBR *generation* resource
  - Covered under IBR revisions to standards
  - Interpretation understands batteries draw current to charge



BESS Capacity – DOE 2020

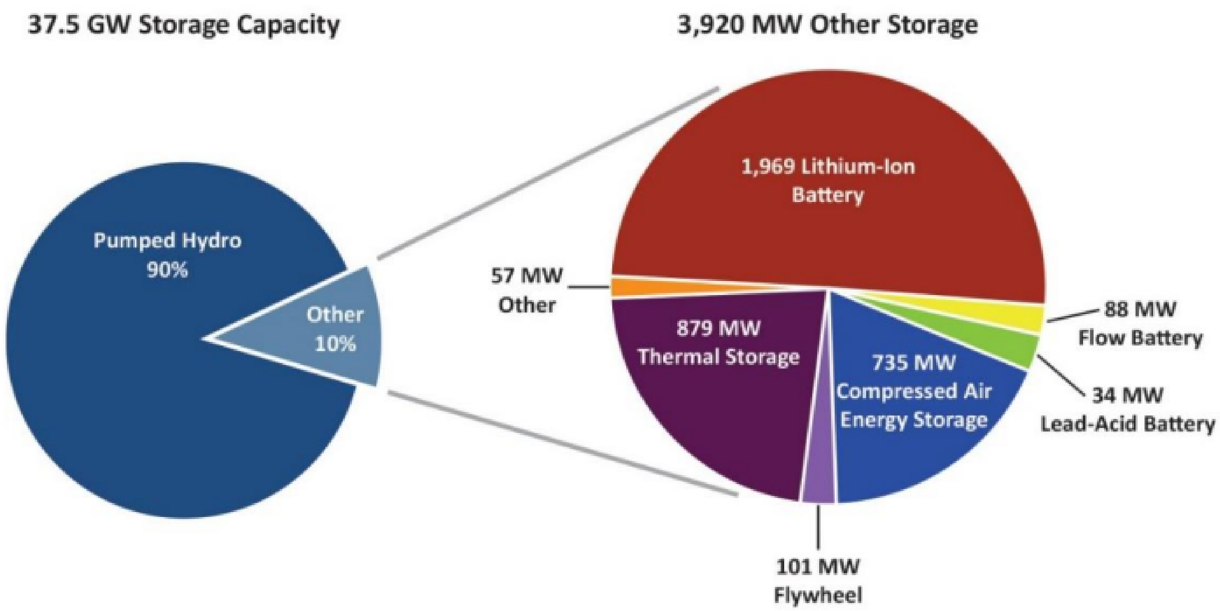
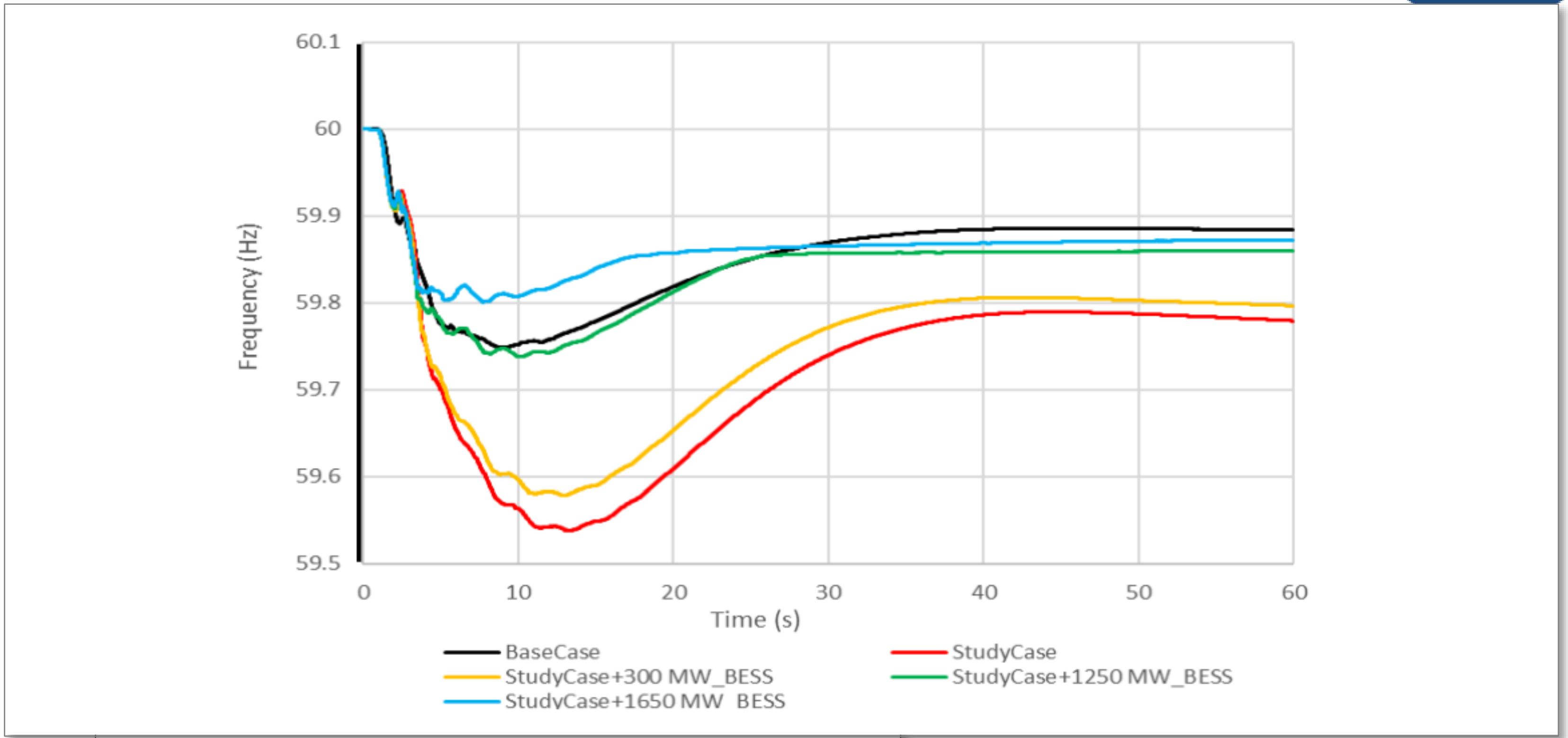
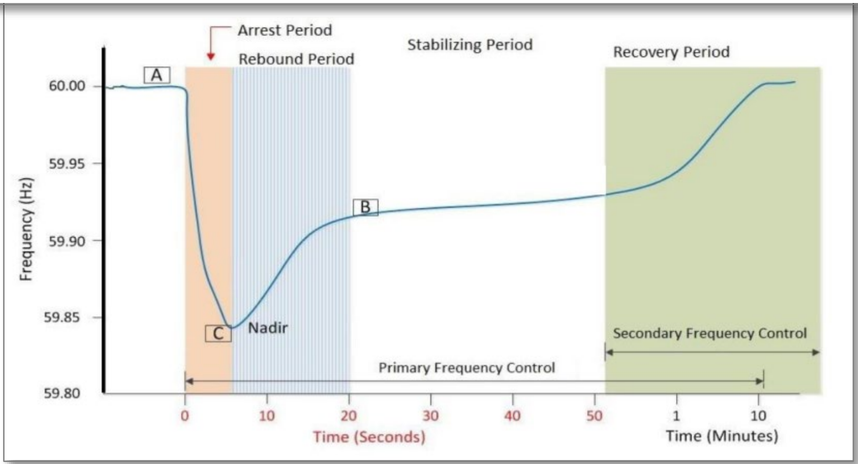


Figure 1.3: Electric Storage Capacity in the United States and Canada, by Type of Storage Technology[14]

BESS Performance in UFLS Mitigation





BESS Over and Under Frequency

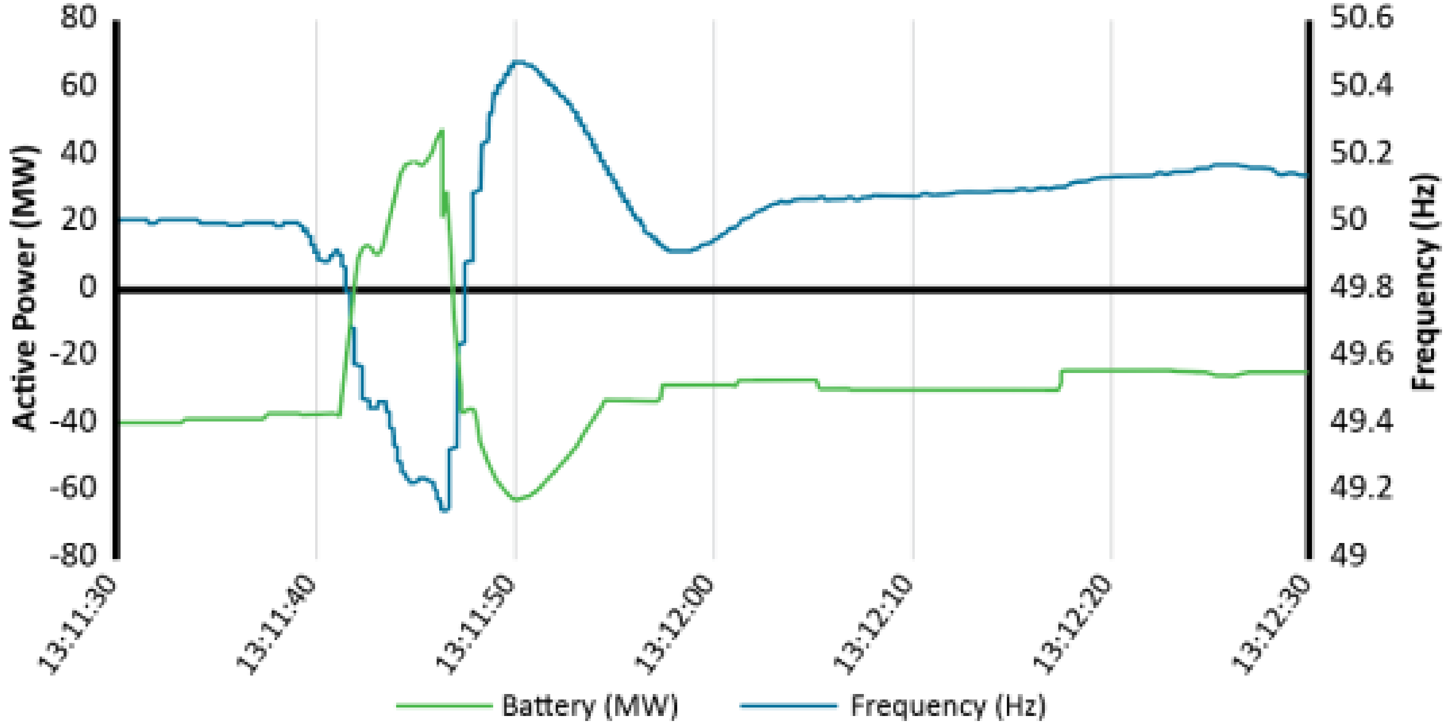


Figure 4.10: Hornsdale Battery Performance Due to the August 25, 2018, Event

Questions and Answers

Storage resource participation in the CAISO

Danny Johnson, Market Design Sector Manager
Market Design & Analysis – California ISO

October 12, 2023

Overview of todays presentation

- Background and basics
- Market Participation
  - Energy awards
  - Ancillary service awards
- Other Considerations
- Open discussion; Q/A

Storage Resource Basics

- Market revenues are purely based on price arbitrage
  - Can both charge by consuming power (during low prices) and provide power to the grid (during high prices)

- State of Charge **(SOC)** is the parameter that tracks how much energy the battery has available; is optimized by the day-ahead and real-time markets. MWh units

- When combined with multi-interval optimization allows the market to dispatch storage based on buy/sell spreads

The CAISO offers 3 different models for storage resources can use to participate

- Non-Generator Model: Full +/- biddable range, no transition times

- Hybrid Model: Single modeled resource behind a point of interconnection that includes variable energy resource (VER) and storage resource; CAISO market optimizes total output of project

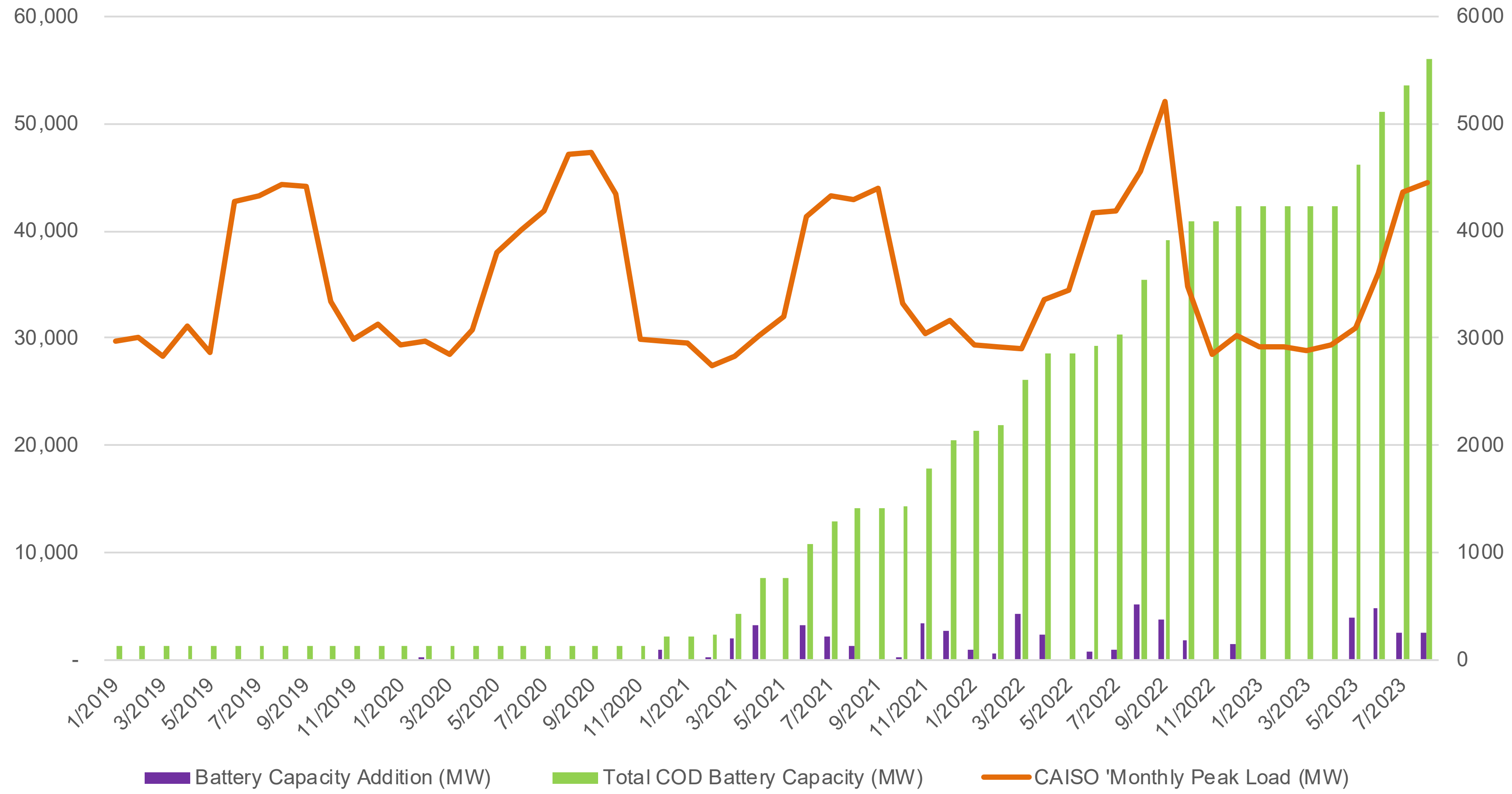
- Co-located Model: Multiple VER and storage resources behind single point of interconnection; marketer separately manages bid submission for both resources. Used to prevent grid charging to maintain ITC’s

Storage resources are an important component of CAISO's ability to manage its control area

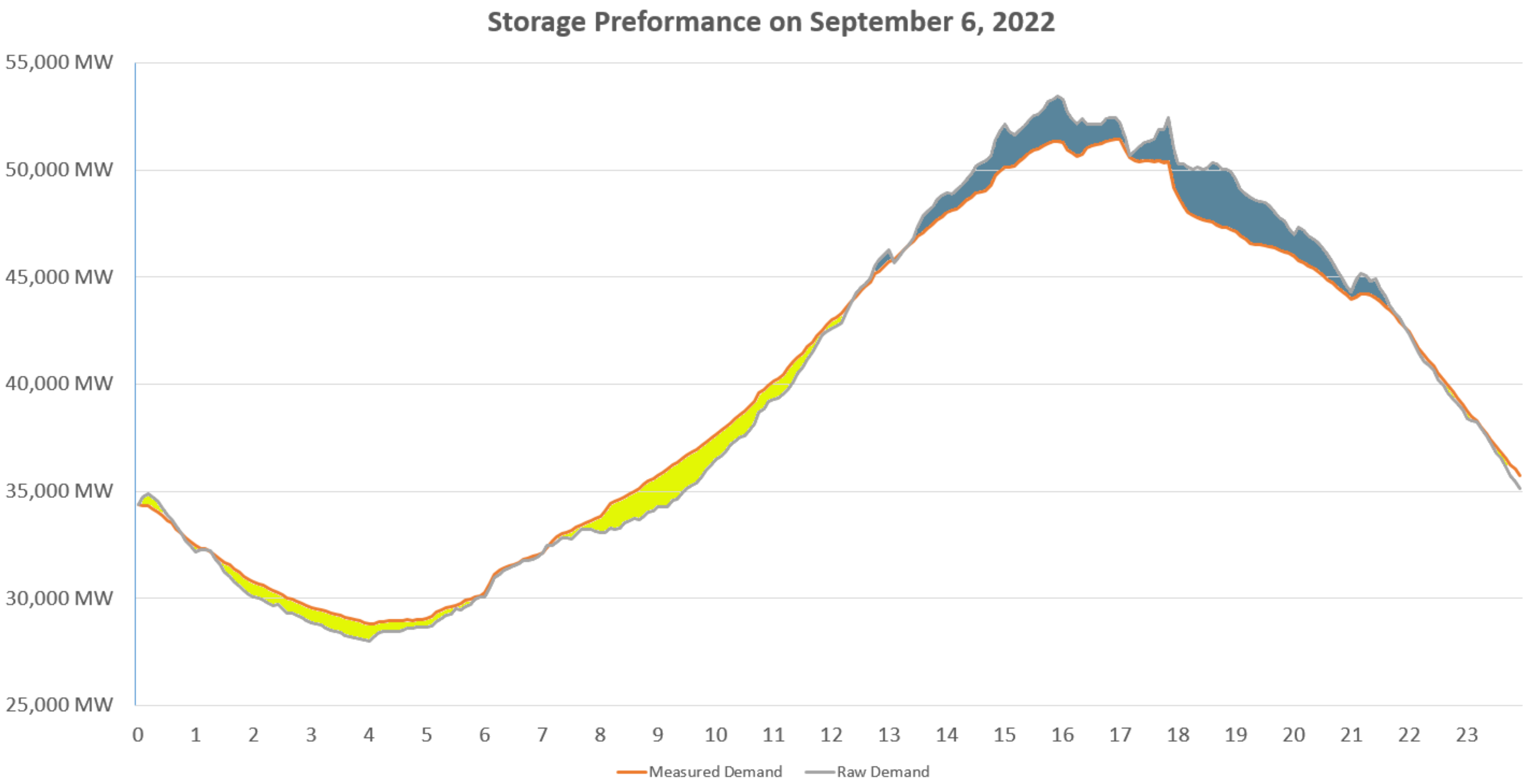
- Allows CAISO to utilize supply from VER's throughout the day
  – Lower total production costs through optimal use of VER energy throughout the day

- Technology largely removes ramping limitations;
  – Ideal for providing ancillary services (regulation and contingency reserves)
  – Helpful in efficiently managing transitions and ramping within thermal fleet as well as ramps associated with VER supply

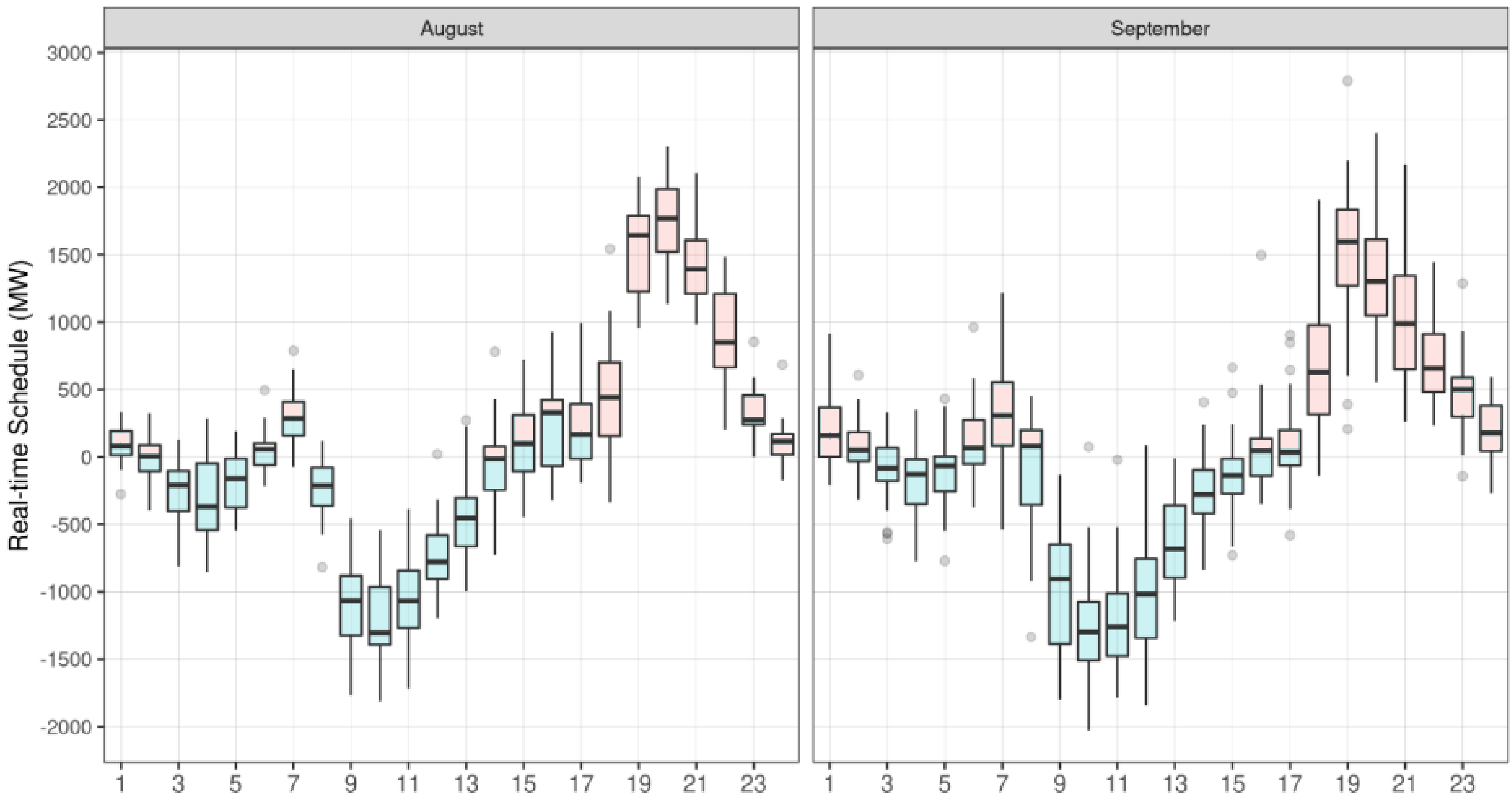
CAISO Monthly Peak Load Battery Storage Capacity



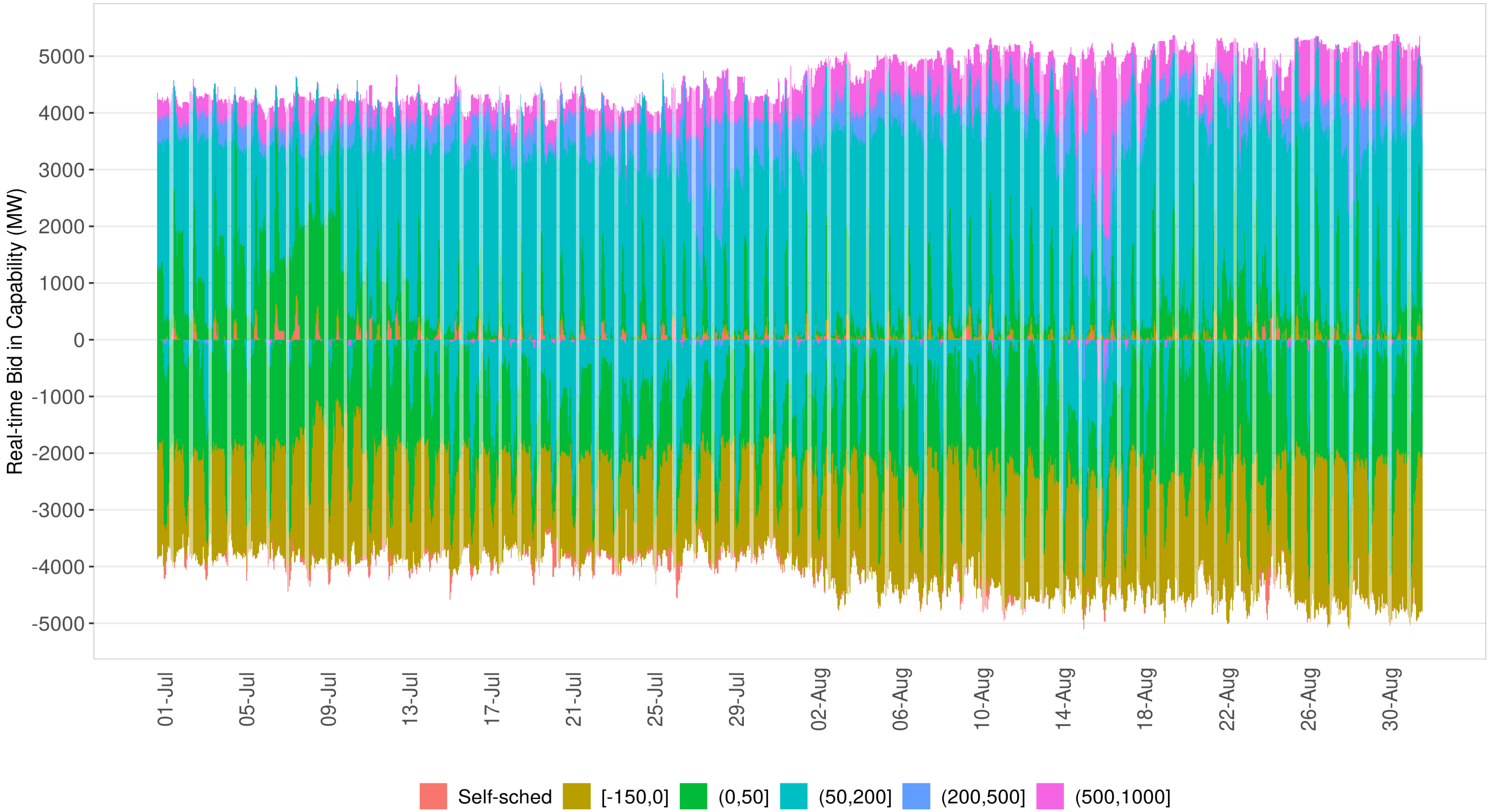
CAISO system all time peak load shaped via storage



Hourly distribution of real-time market storage resource schedules: late summer 2022



Recent economic participation of storage resources is robust in the CAISO's markets



Storage resources energy awards

- Positive energy awards indicate discharge awards, SOC decreases
- Negative energy awards indicate charging awards, SOC increases by Energy Award * Charge Efficiency
  - Storage is not 100 % efficient
- Energy awards are limited in both directions by SOC

Storage Basics – Modeling a 4-our resource example

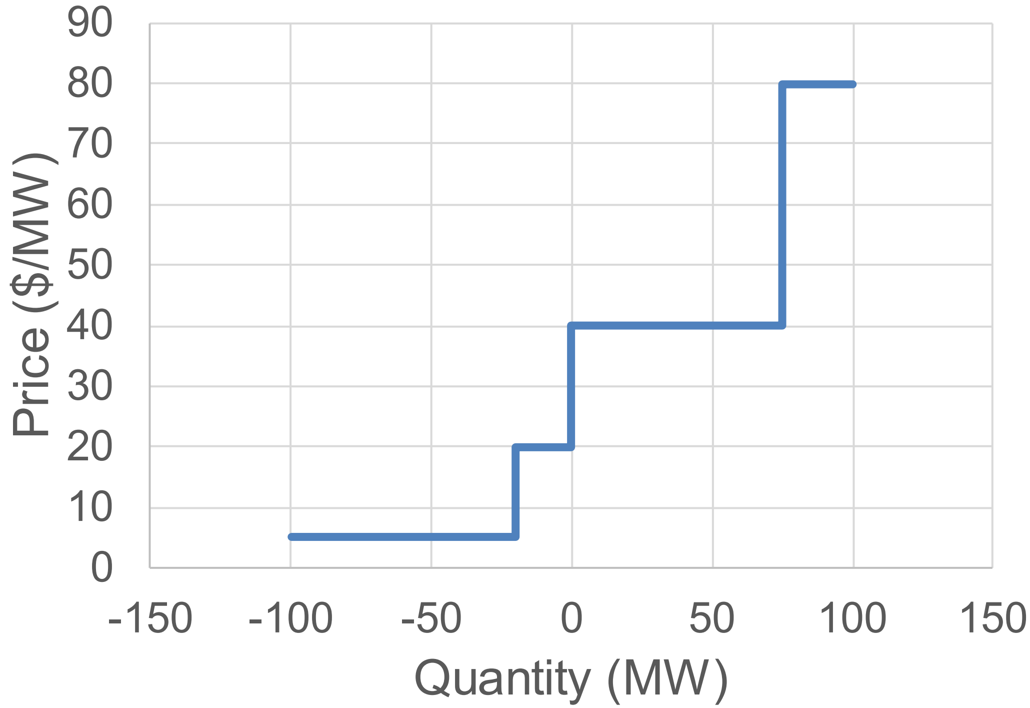
$$SOC = SOC_{i,t-1} - \left(P_{i,t}^{+} + \eta P_{i,t}^{-}\right)$$

Pmax	100 MW	Maximum Output
Pmin	-100 MW	Maximum Charging level
Charge Efficiency (η)	0.8	Efficiency when charging
Minimum SOC	0 MWh	Minimum amount of charge in battery
Maximum SOC	400 MWh	Maximum amount of charge in battery
Ramp Rate	100 MW/min	How fast resource can ramp

Storage Resource – Energy Bid Curves

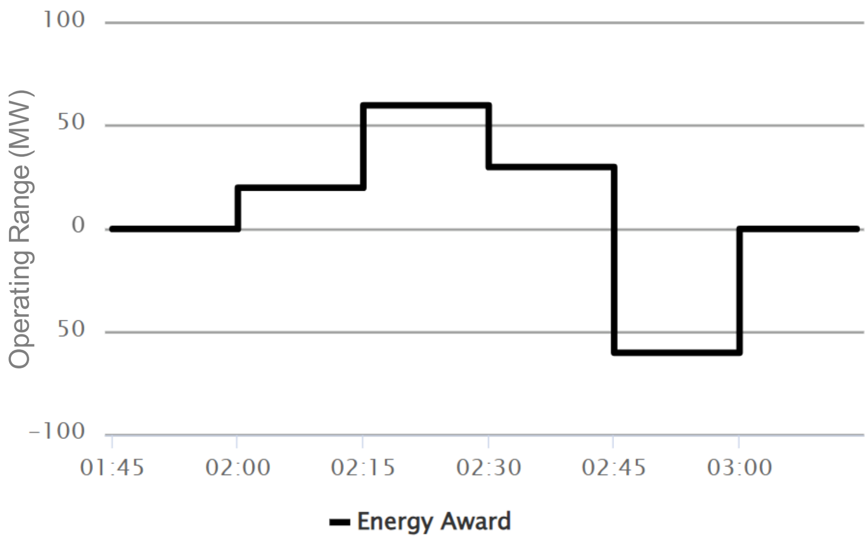
Energy Bid

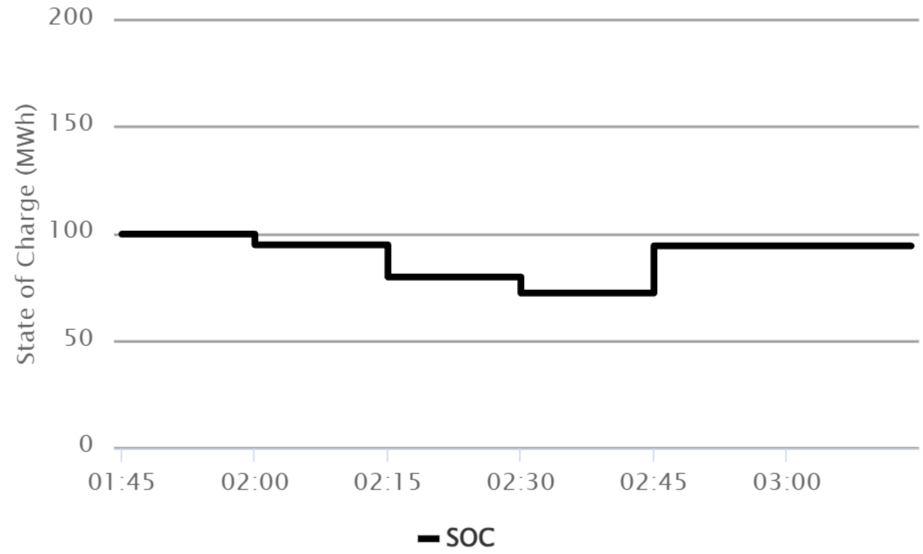
Quantity (MW)	Price ($/MW)
-100	5
-20	20
0	40
75	80
100	80



- What is lowest price resource will purchase power to charge?
- What is lowest price resource will provide power to grid?
- Bids must be monotonically increasing through entire range

Energy Awards – Real Time Market Example



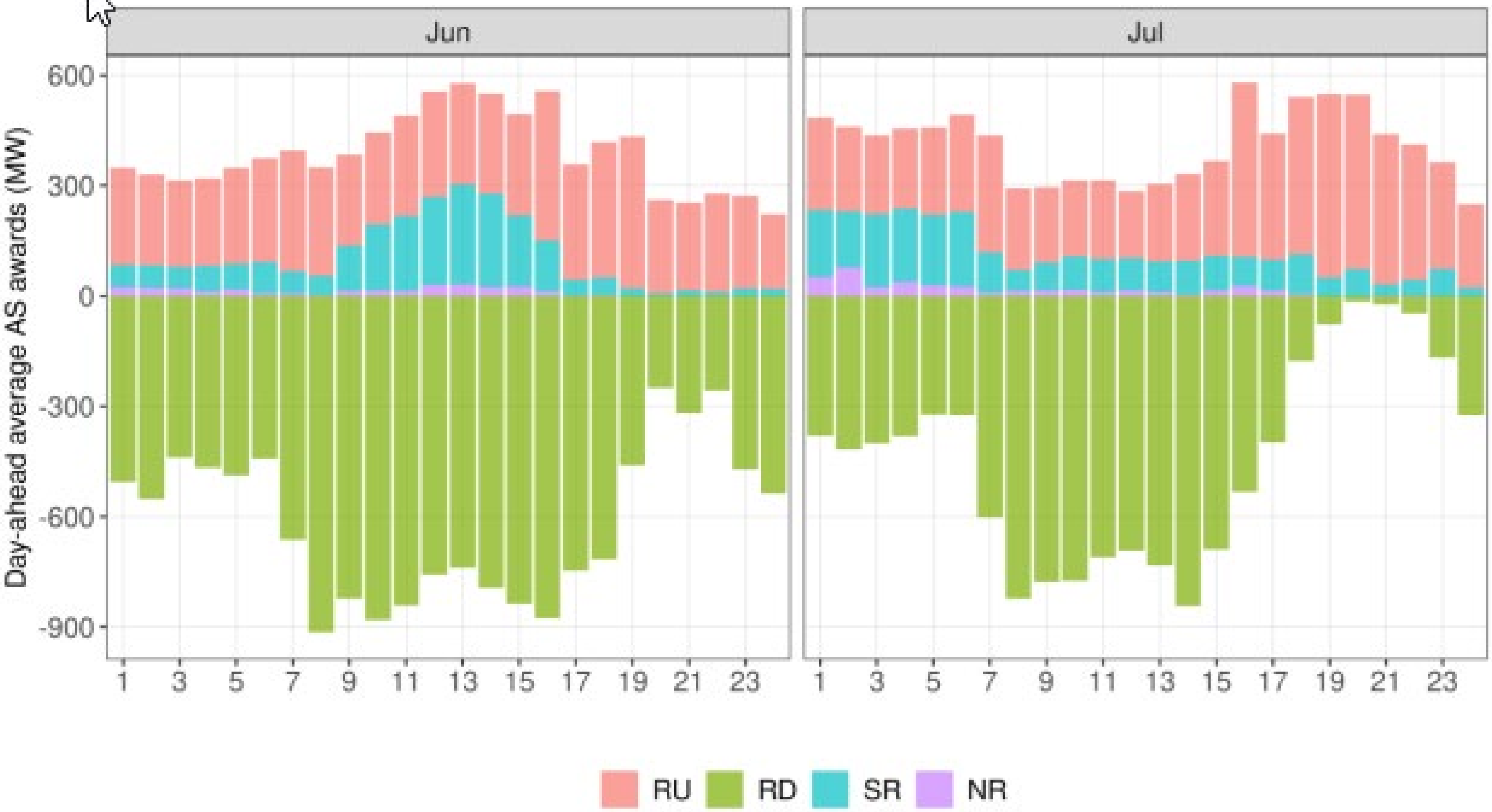


Time Interval Start	Energy Award (MW)	Change in SOC (MWh)	SOC (MWh)
1:45	0	0	100
2:00	20	-5	95
2:15	60	-15	80
2:30	30	-7.5	72.5
2:45	-60	+12	84.5
3:00	0	0	84.5

Storage Resources - Ancillary Services

- Can provide all types of ancillary services using full operational range, from Pmin to Pmax
- Fast ramp rates mean storage resources can, and have been **observed** providing significant amounts of ancillary service awards
- Maintaining SOC for AS awards, whose conversion to energy is inherently uncertain can provide a challenge
  - For upward AS (regulation and contingency reserves) must have sufficient SOC
  - For downward AS (Rd) must have sufficient headroom on SOC to maintain charging award
  - How can an system operator ensure ancillary service awards are feasible in RT?

Daily Ancillary Service Awards for June and July 2023



Ancillary Service - State of Charge Management

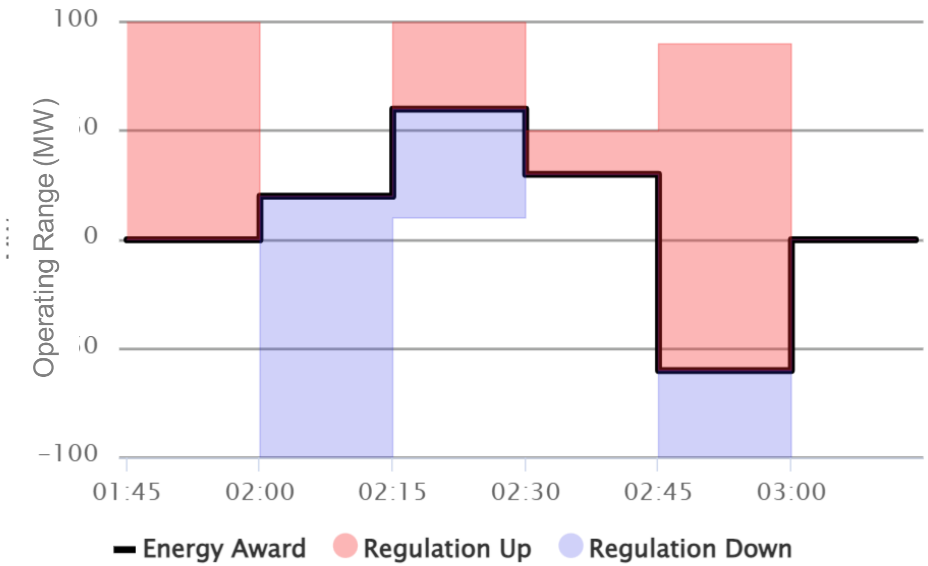
Day Ahead

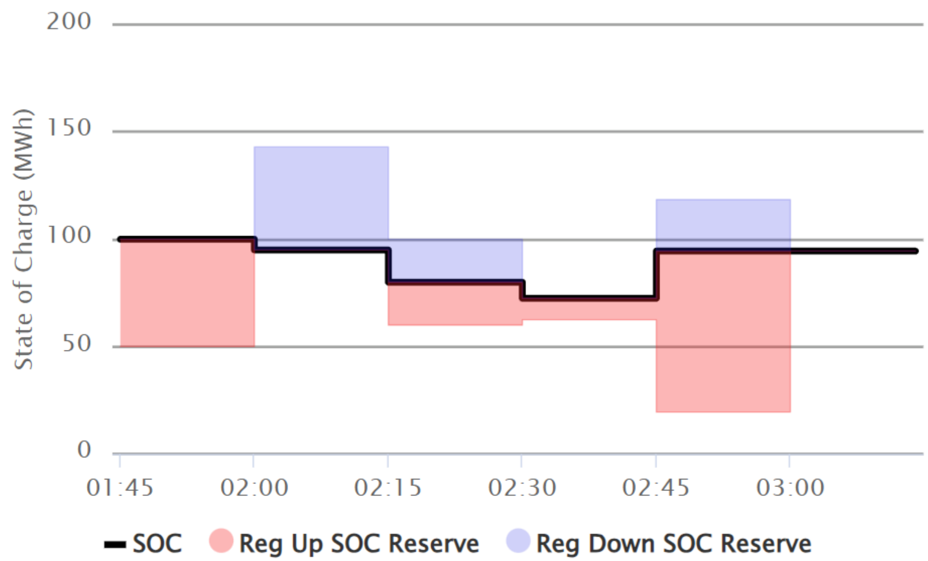
- Consider AS within the optimization?
- $SOC = SOC_{i,t-1} - (P_{i,t}^{+} - \eta_i P_{i,t}^{-} + \mu_1 RU_{i,t} - \mu_2 \eta_i RD_{i,t})$
  - What assumptions should be made for conversion of reliability service capacity awards to energy?
  - Potential to temporally link regulation and energy awards through a day-ahead market horizon

Real Time

- Constraints that ensure minimum levels of SOC?
- Discipline through pricing?

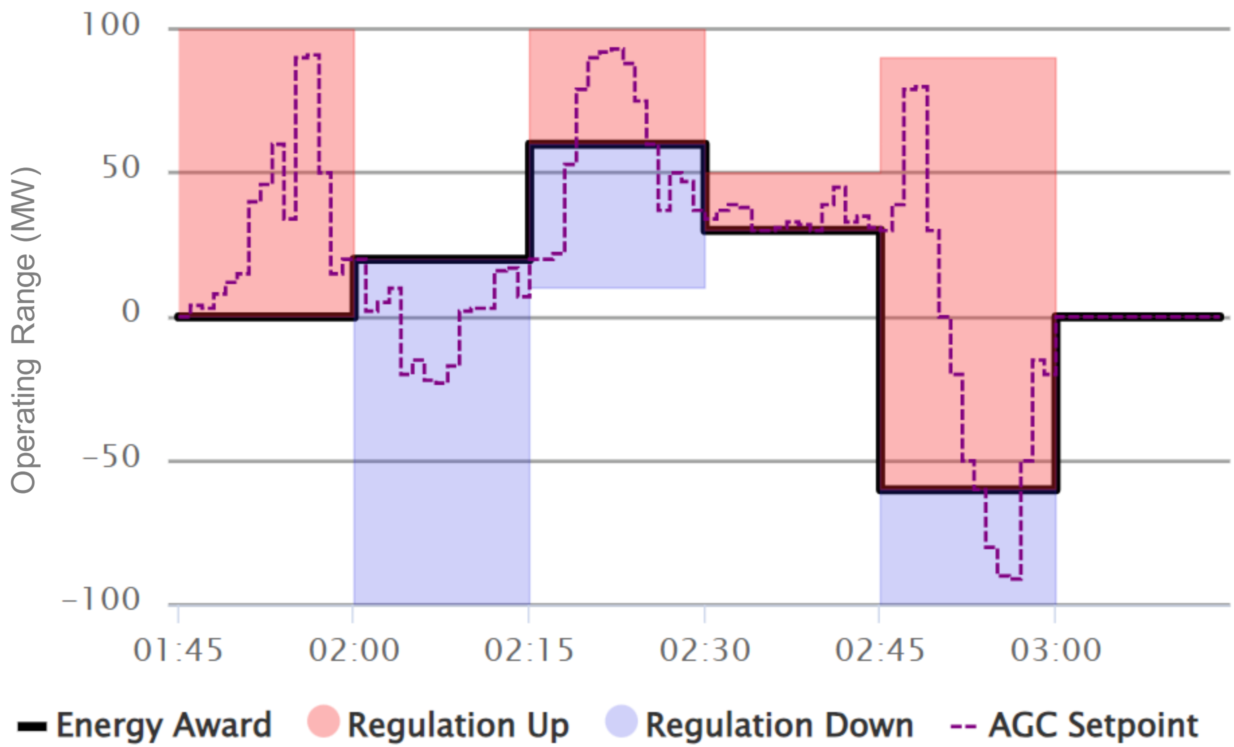
Ancillary Services – Multiple Intervals





Time Interval Start	Energy (MW)	SOC (MWh)	Reg Up (MW)	Reg Down (MW)
1:45	0	100	100	0
2:00	20	95	0	120
2:15	60	80	40	50
2:30	30	72.5	20	0
2:45	-60	94.5	150	60
3:00	0	94.5	0	0

Ancillary Services – Example Multiple Intervals



In real-time, Automatic Generator Control (AGC) sends 4 second telemetry to resource. The cleared regulation up and regulation set the range of MW that AGC may dispatch the resource in

Storage resources present unique considerations

Multi interval optimization: The CAISO runs a cost minimizing optimization across an extended real-time market horizon

- What is the appropriate treatment for arbitrage resources with 1 binding and many advisor intervals?
- How should bid cost recovery / make whole payments work?

Capacity Planning: The majority of storage resources do not have access to fuel such that they can provide consistent capacity for an operating day

- How does this factor into resource adequacy

Multi-Interval Optimization

- Each real-time market run looks out into future intervals, however only binding interval is settled
- Market will optimize on bid spread, rather then prices
- When resource is near min or max SOC range, the future awards can impact binding interval, although they do not impact settlement

Binding	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory
1:00	1:05	1:10	1:15	1:20	1:25	1:30	1:35	1:40

Binding	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory
1:05	1:10	1:15	1:20	1:25	1:30	1:35	1:40	1:45

Binding	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory
1:10	1:15	1:20	1:25	1:30	1:35	1:40	1:45	1:50

Multi-Interval Optimization – Hypothetical example

Interval	Binding	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory	Advisory
Time	1:00	1:05	1:10	1:15	1:20	1:25	1:30	1:35	1:40
LMP ($)	$200	$100	$100	$500	$500	$500	$500	$250	$150
Energy (MW)	0	0	0	60	60	60	60	0	0
SOC (MWh)	20	20	20	15	10	5	0	0	0

- Resource may not be dispatched in binding interval due to limited SOC, higher prices later on in case
  - If advisory prices are not published participants cannot see why they were not dispatched
- Future high prices are not guaranteed to materialize, have no settlement impact
  - During extended periods of stressed operating conditions incentive compatible dispatch decrease

Storage resources create additional questions in capacity planning

- To the extent capacity planning is done on a more granular interval then meeting daily peak load assumptions have to be made regarding energy use limited resources
  - Is maximum discharge assumed for a more limited window?
  - When over a daily horizon should storage be assumed to charge / discharge

- To the extent storage is not utilized in a market environment prices and dispatch need to support the assumptions made in the forward planning process

Acknowledgements

The materials presented today were produced by

- CAISO, Market Analysis and Forecasting
- CAISO, Customer Readiness
- CAISO, Operations Policy and Analytics

Questions?

NPCC 2023 – 2026 Strategic Plan

Strategic Focus Area

Reliably Integrate Resources Brought Forward by Decarbonization Objectives

- 2023 DER/VER Forums - April, May, August, October
  - Transmission Integration
  - IEEE 2800
  - Offshore Wind
  - Battery Storage
- Grid Security Conference – GridSecCon 2023
  - Quebec City October 17-20, 2023
- NPCC DER/VER Guidance Document --- DER Reporting Form

NPCC 2023 Outreach Activities

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NPCC 2023 Corporate Goals and Strategic Plan

NPCC DER/VER Guidance Document