Challenges of Modern Power Grid Operations

(Power Grid Operations Generative AI)

AI-driven Solutions for Energy's Future
K-PAI Forum #11

September 2025

Contents

PG&E celebrated the 100th anniversary of the Pit1 power plant and Vaca-Dixon substation in September 2022. At one time, it was the largest substation and highest-voltage transmission line in the world.

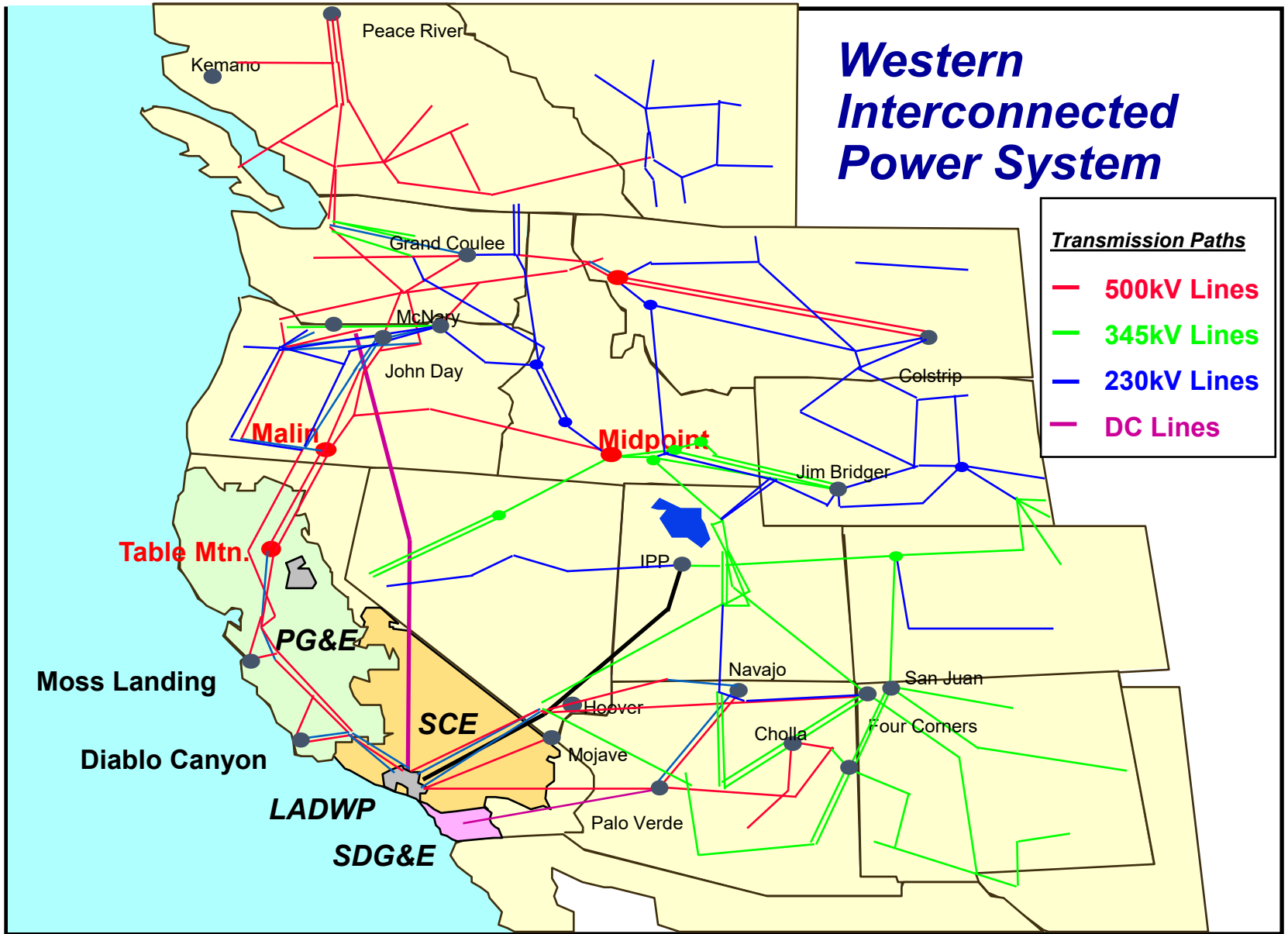
300MW of Power & 230KV Transmission Line

A Century of Clean Power: Events Marke...

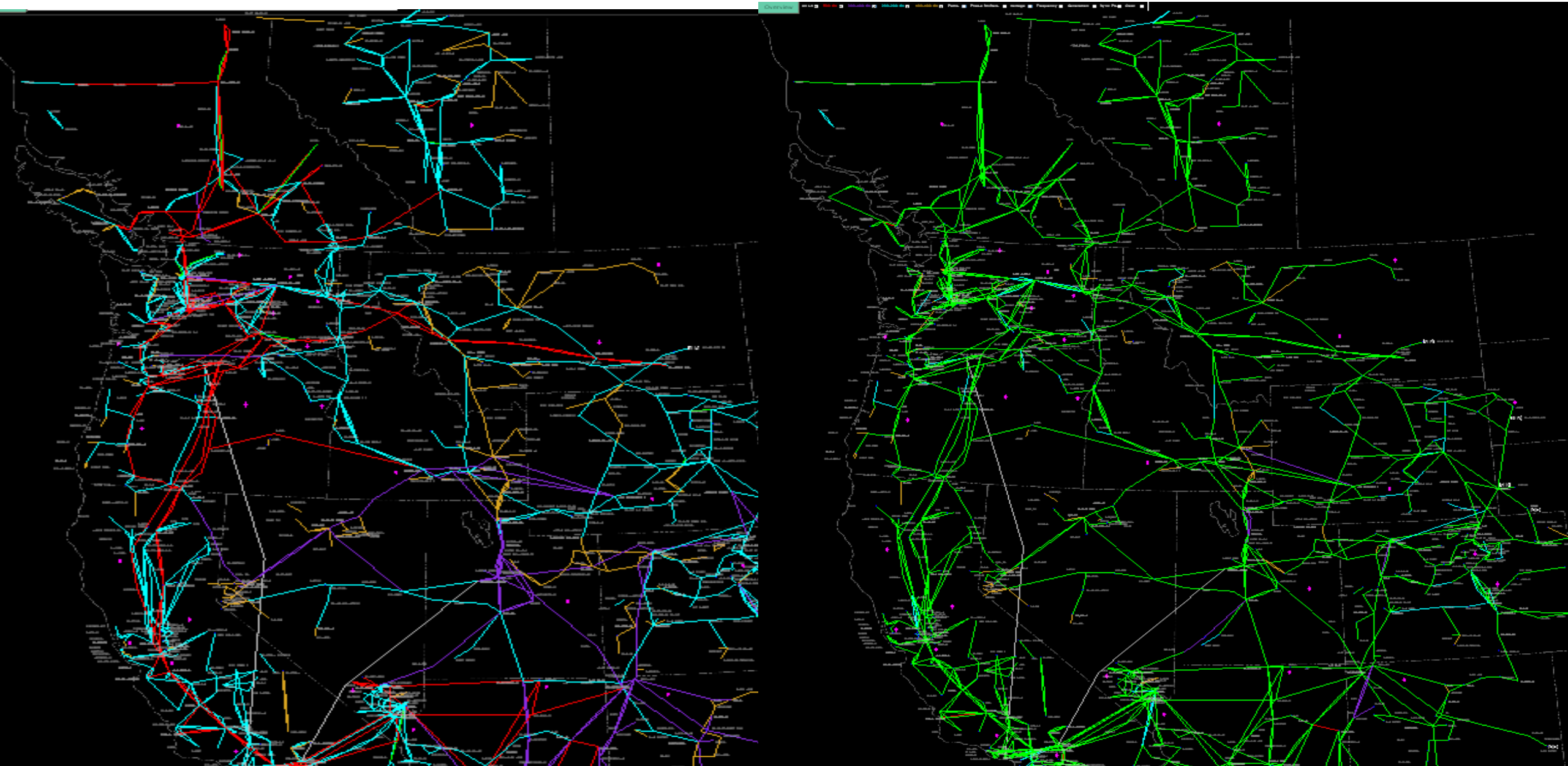
PG&E marks 100th anniversary of Vaca-...

Western Interconnection

Power Grid Operations Challenges: Voltage, Frequency & Demand



BLACKOUT CHALLENGES
ON (Energized Grid) and OFF (Total Blackout)



Renewable Energy Operations Challenges
– IBR (Inverter Based Resources)
– GFR/GFL/GT (Grid Forming, Grid Following, Grid Tie) Inverters

Solar:
DC to 60HZ AC

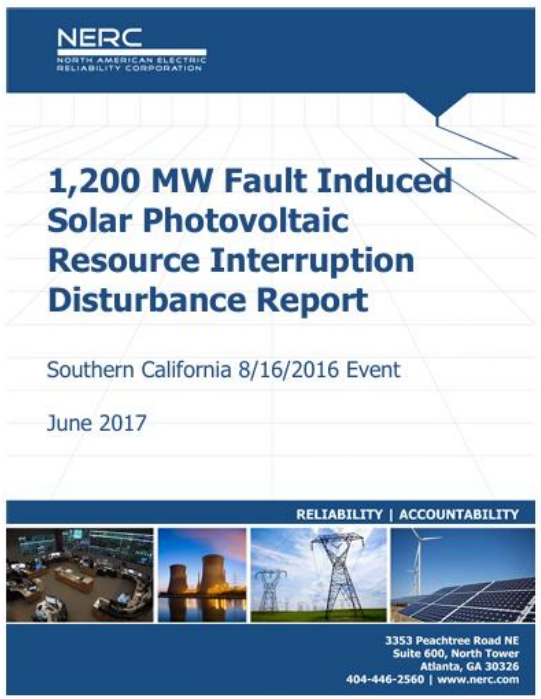
Wind: Variable AC to
DC to 60HZ AC

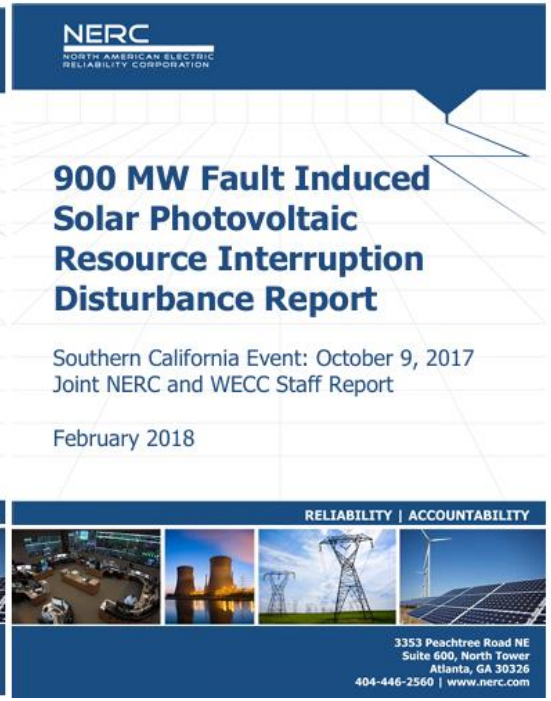
BESS/ESS (DC to 60HZ AC)
Battery Energy Storage System

DC-Direct Current
AC-Alternating Current

Inverter Control and Maintenance: GT (Grid Tie), GFM (Grid Forming) and GFL (Grid Following) Inverters

- 2016 and 2017 Solar Disturbance in Southern California
  - Solar tripped prior to Grid relays. Introduced trip-delay to inverters.

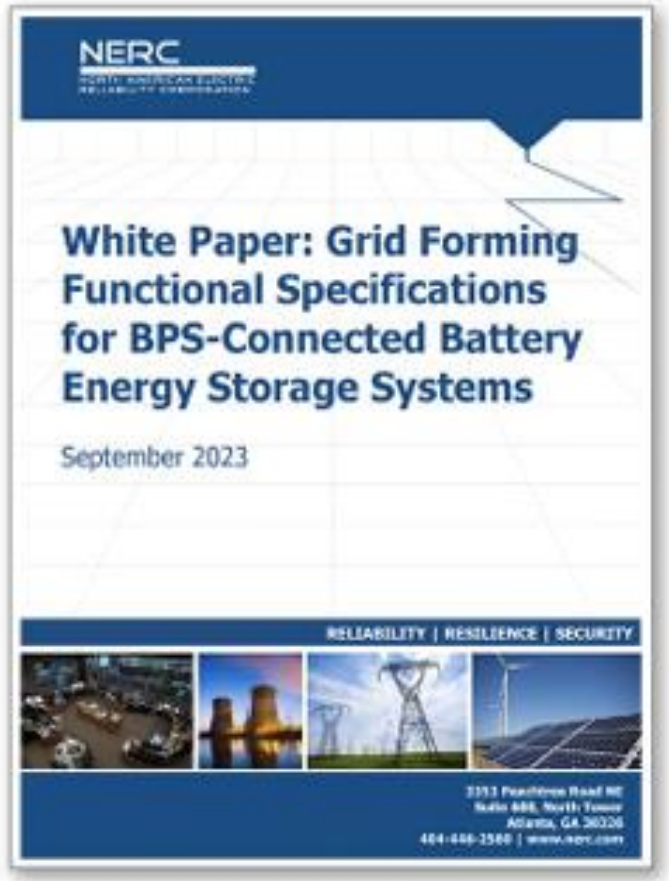




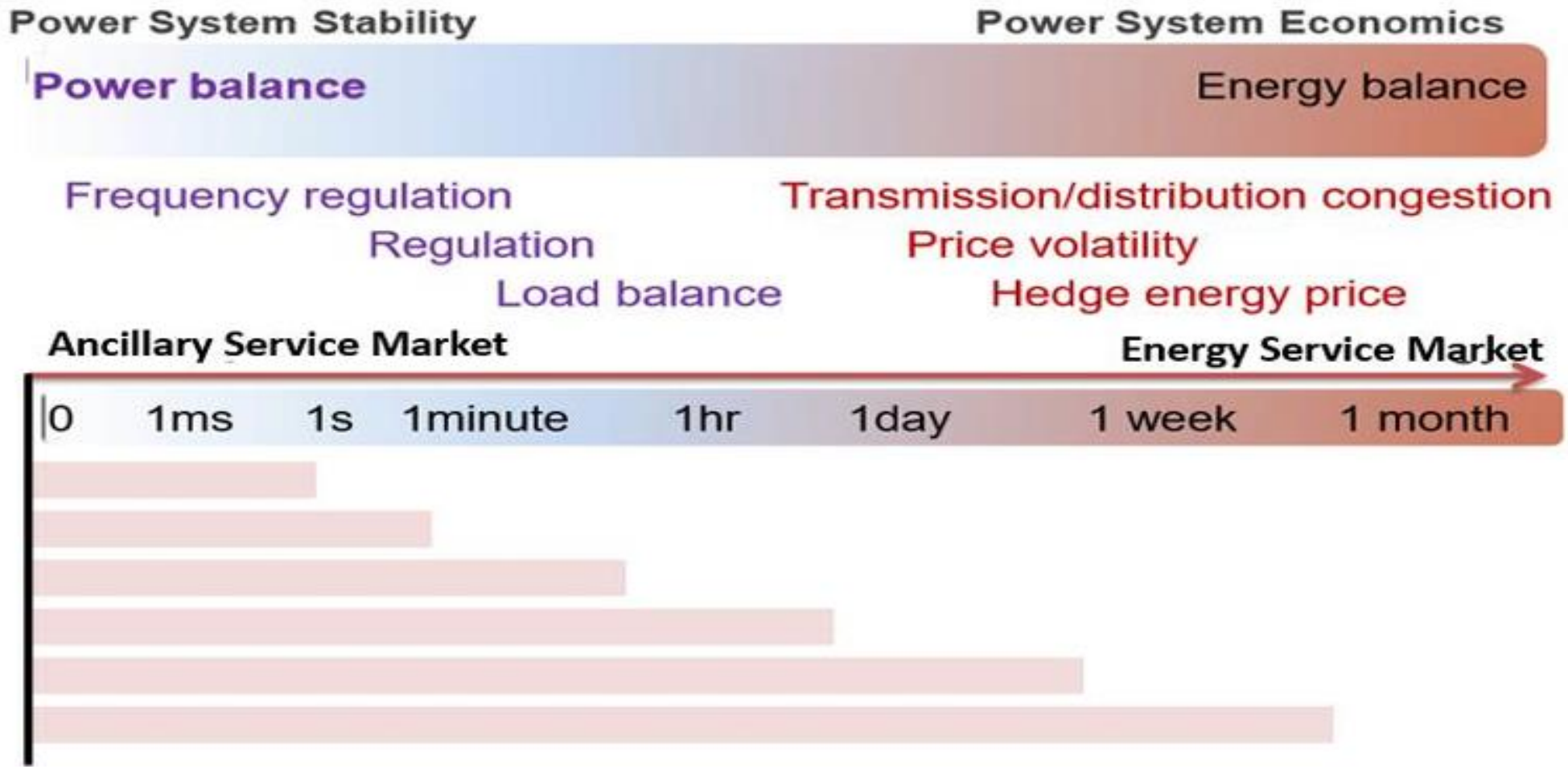
- 2025 Iberia Peninsula Blackout

-Blackout caused Inverter Control Failure.
-Absence of GFM Inverter.
-Progressing investigations.

NERC GFM Whitepaper



Power Grid Market Challenge
Technical Concept of Power Market Operations: Time and Service Considerations
Ancillary Service Market and Energy Service Market



Conceptual ESS in Power Grid: Potential Opportunities for Storage Technology to enhance Reliability in CAISO (California Independent System Operator)

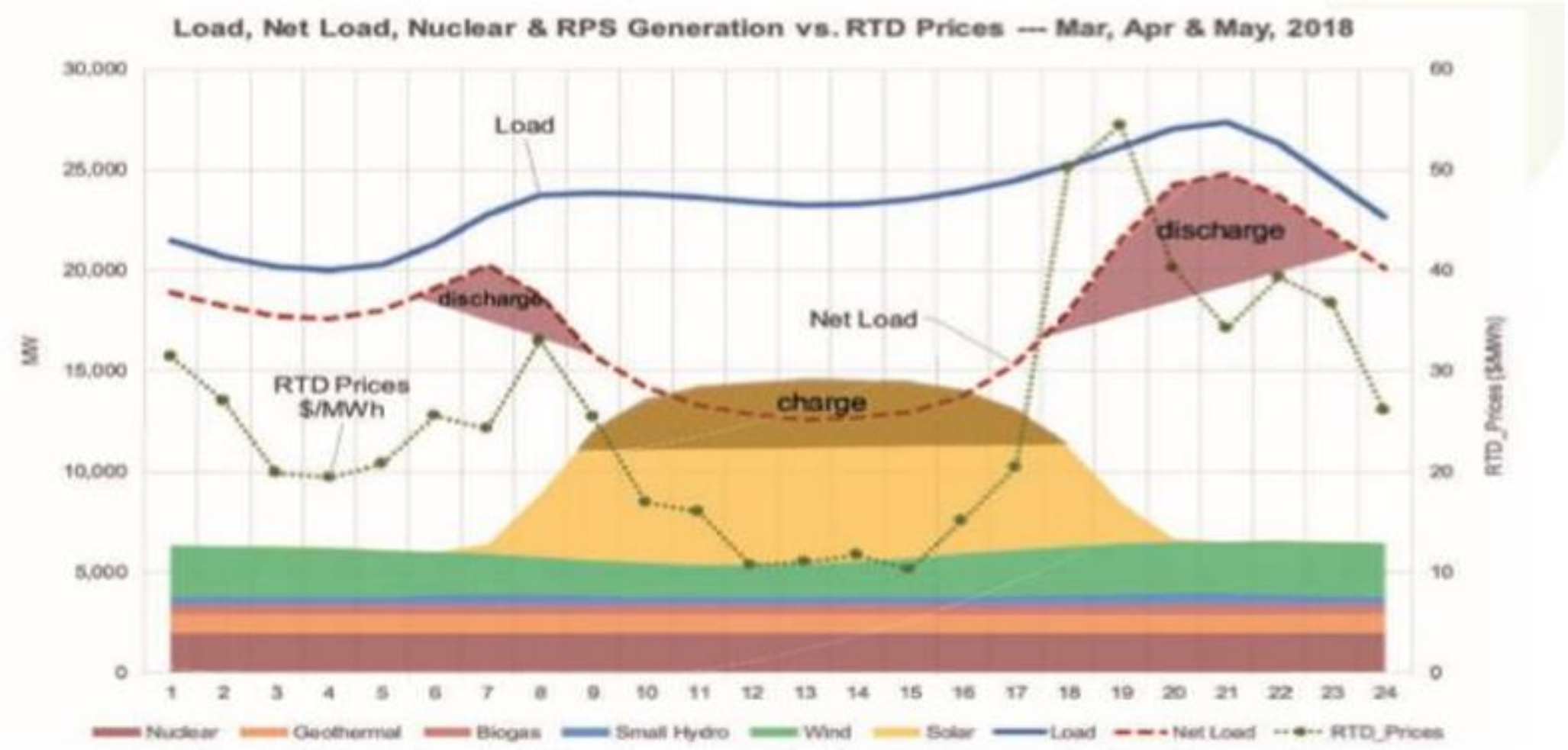
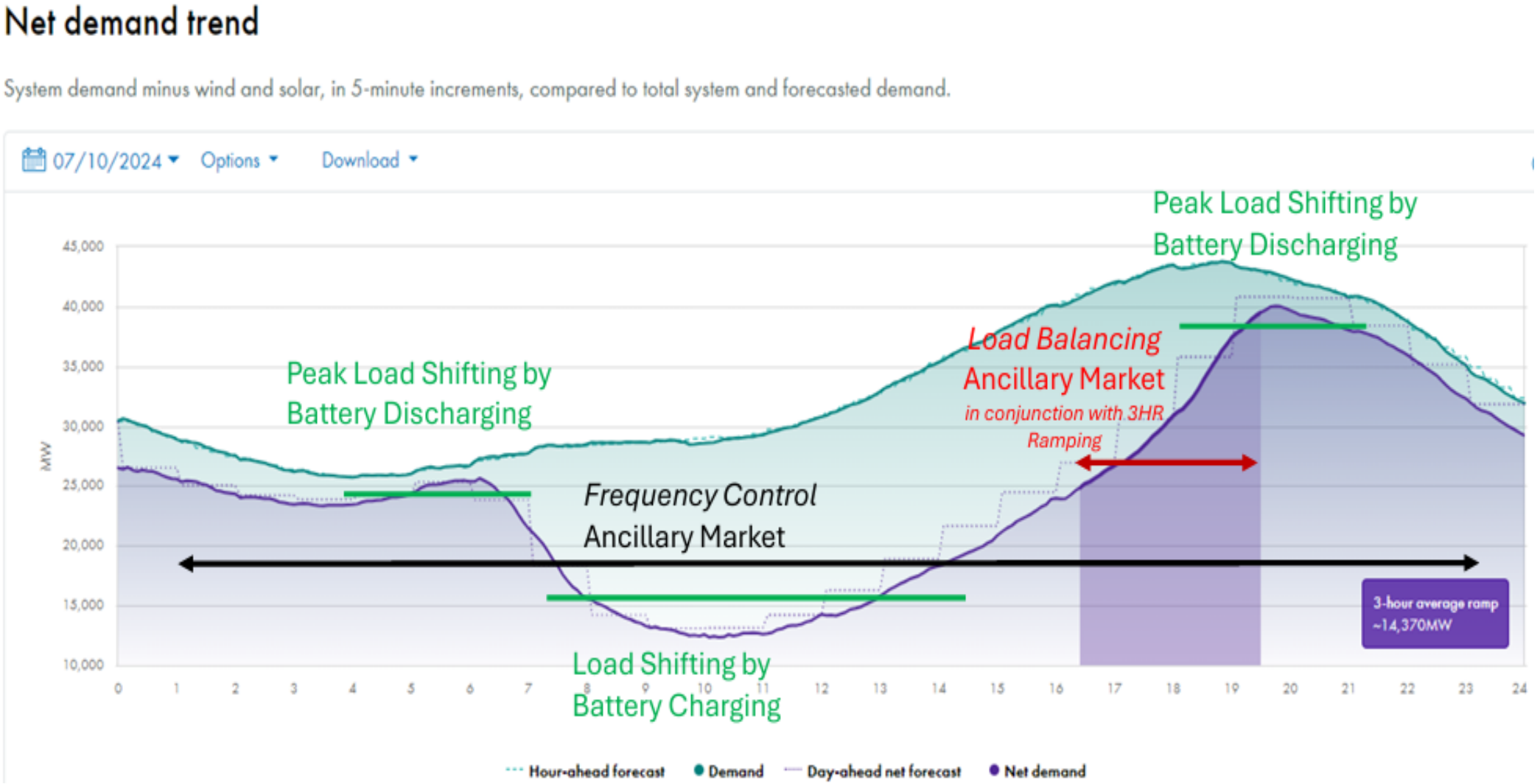


Figure 14: Potential opportunities for storoge technology to enhance reliability. Source: CAISO

CAISO Net demand trend on CAISO System demand minus wind and solar, in 5-minute increments, compared to total system and forecasted demand.

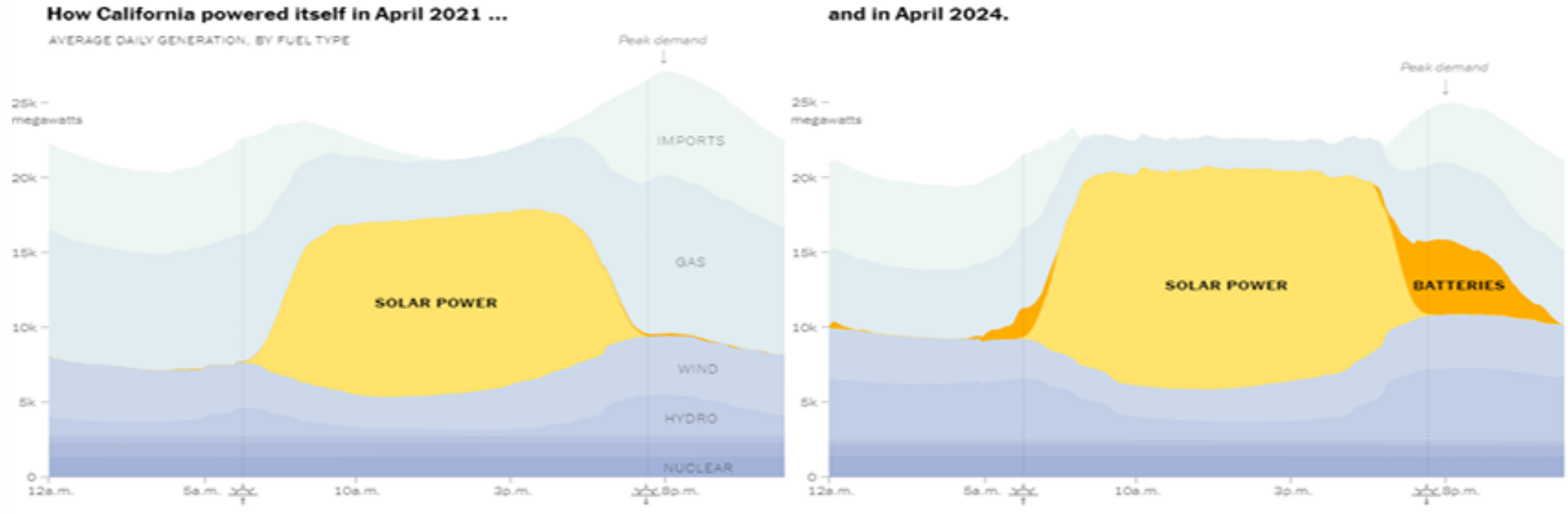


Supply Trend Change in the last 3 Years
April 2021 – Battery Output was over 500MW
April 2024 – Battery Output was over 5000 MW

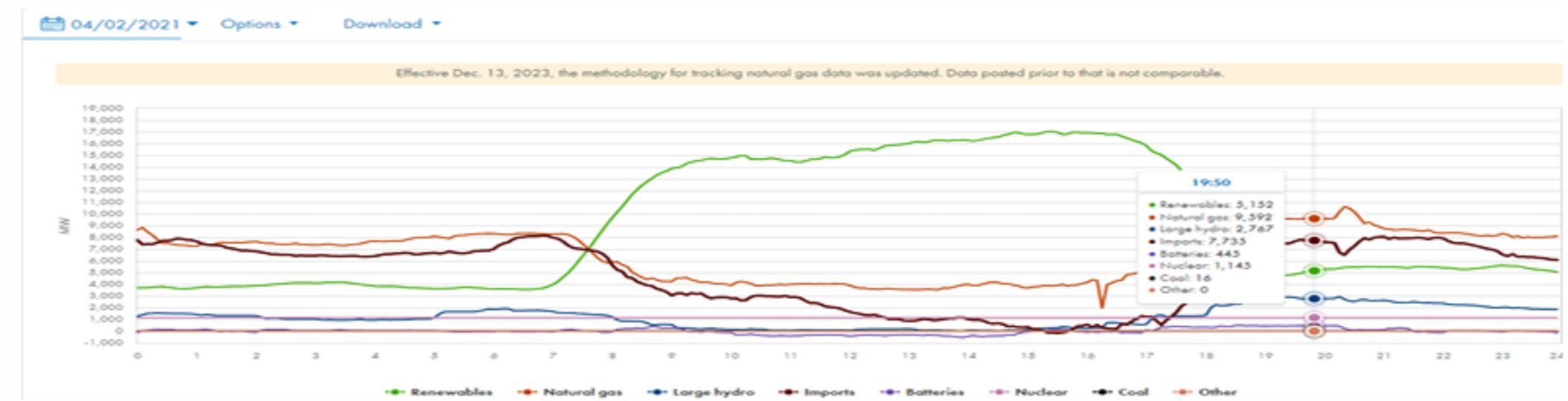
Giant Batteries Are Transforming the Way the U.S. Uses Electricity

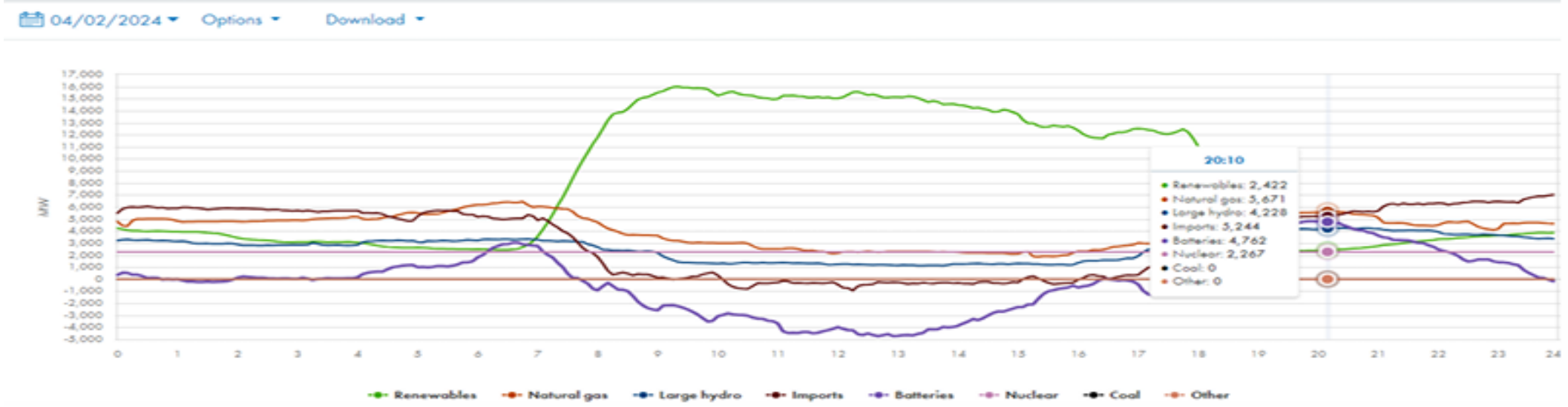
They're delivering solar power after dark in California and helping to stabilize grids in other states. And the technology is expanding rapidly.

By Brad Plumer and Nadja Popovich May 7, 2024



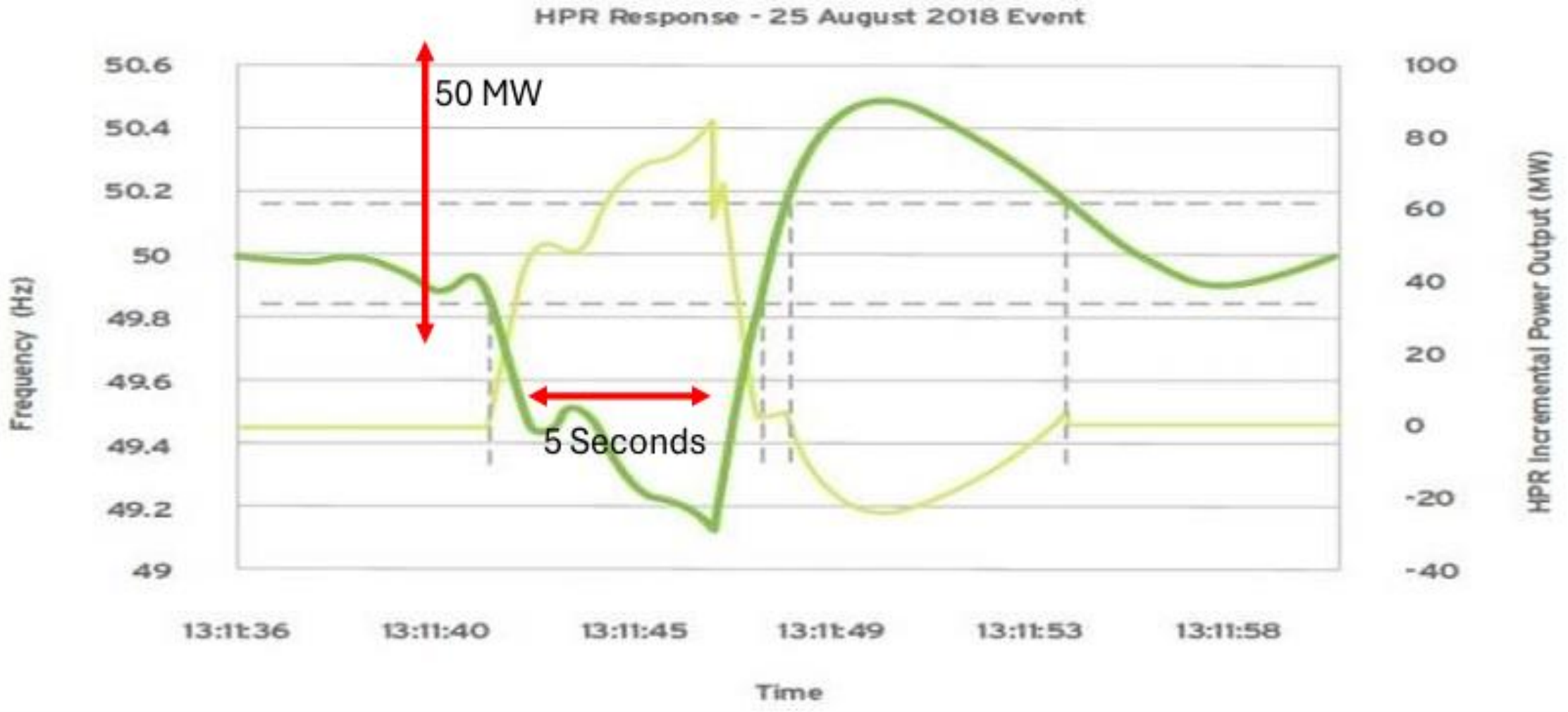
CAISO Supply Trend of 4/2021 and 4/2024





Australia Hornsdale BESS Power Reserve response to “Large System Security Event” on 25 August 2018.

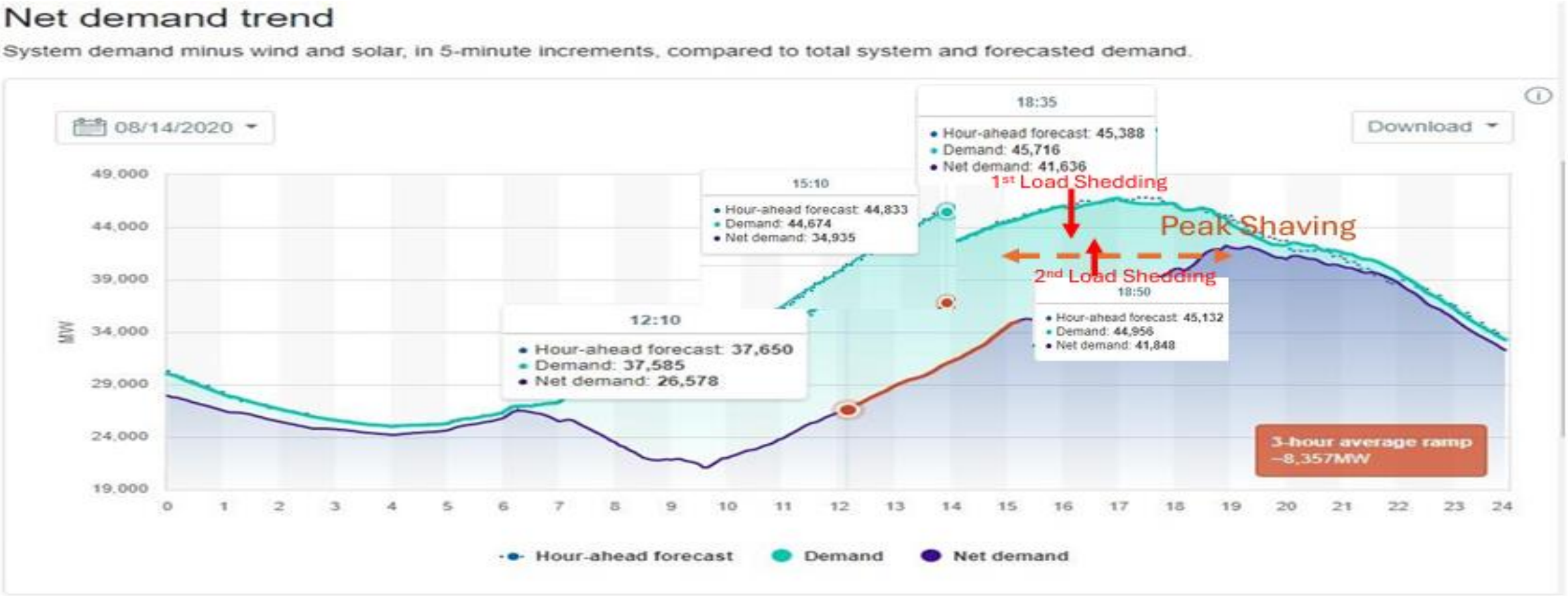
ISOs established different pricing to Ancillary Service Market



Prospective of Commercial Operations at CAISO Market Potential Peak Shaving may will Avoid Load Shedding.

Load Shedding was Triggered due to Reserve Margin Depletion

08/14/2020 CAISO Stage3 from 18:36 to 20:38
PG&E had two Load Shedding at 18:38 and 18:52



Prospective of Commercial Operations Load Balancing and FCAS (see slide 9)

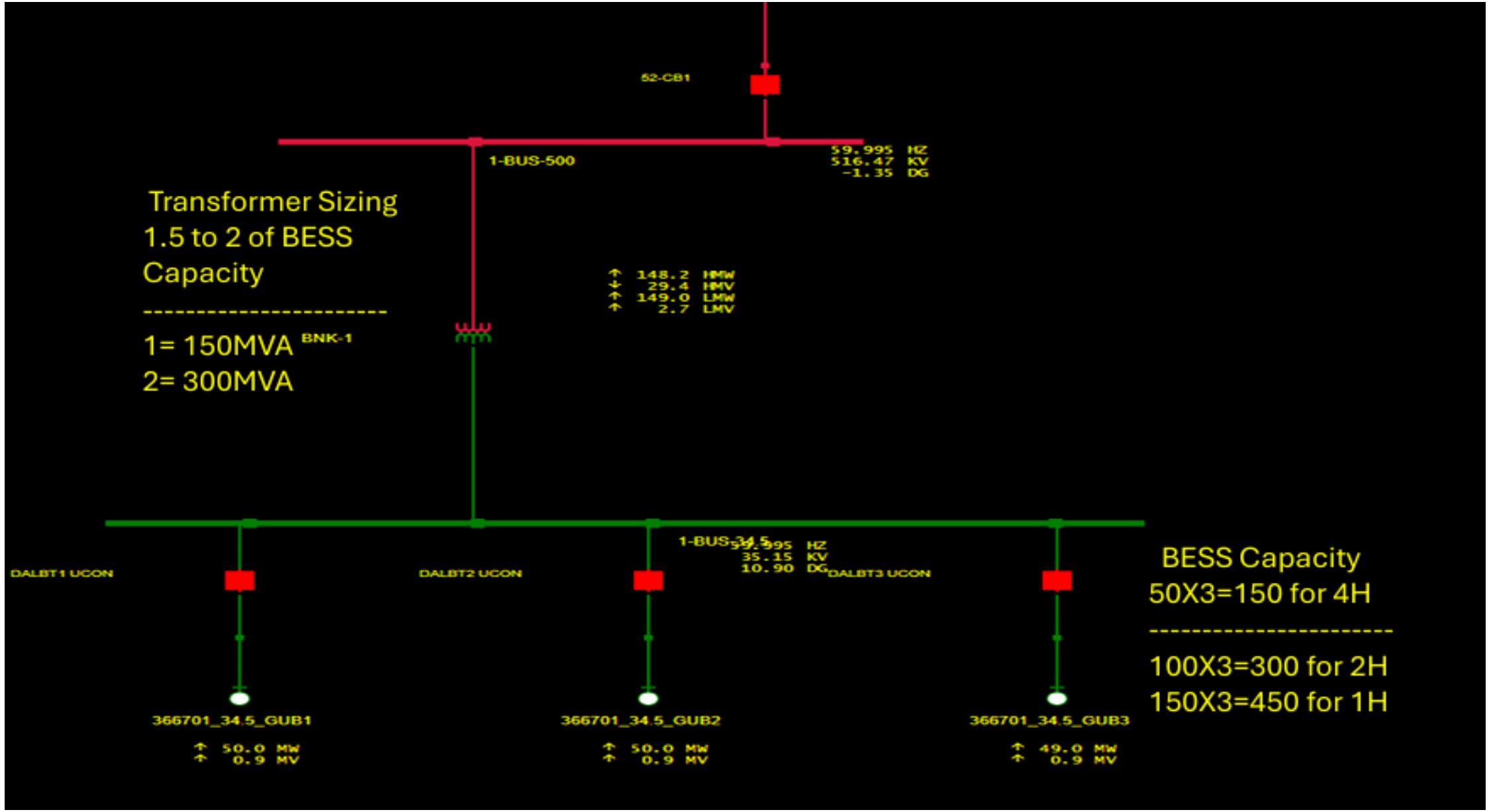
We expect to have Moss Landing Battery Storage Operations in the following areas:

- **Load Balancing** during high ramping period. This is part of the daily operations. It may be part of main business of Battery Storage.

- **FCAS (Frequency Control Ancillary Service)** due to grid disturbances. The Battery Storage will increase the Grid Resilience by increasing the Operating Reserve, and FCAS is a continuous service in 24/7. Also, it may be part of the main business of Battery Storages.

- Interactive Mix of Load Balancing and FCAS in **high MW ramping in 3 hours.** This is a daily event. There are unknown expectations. It could be a great business opportunity of Battery Storage.

Design of BESS Operations: Transformer Sizing and BESS Capacity



NREL - Generative AI for Power Grid Operations

White Paper: Generative AI for Power Grid Operations

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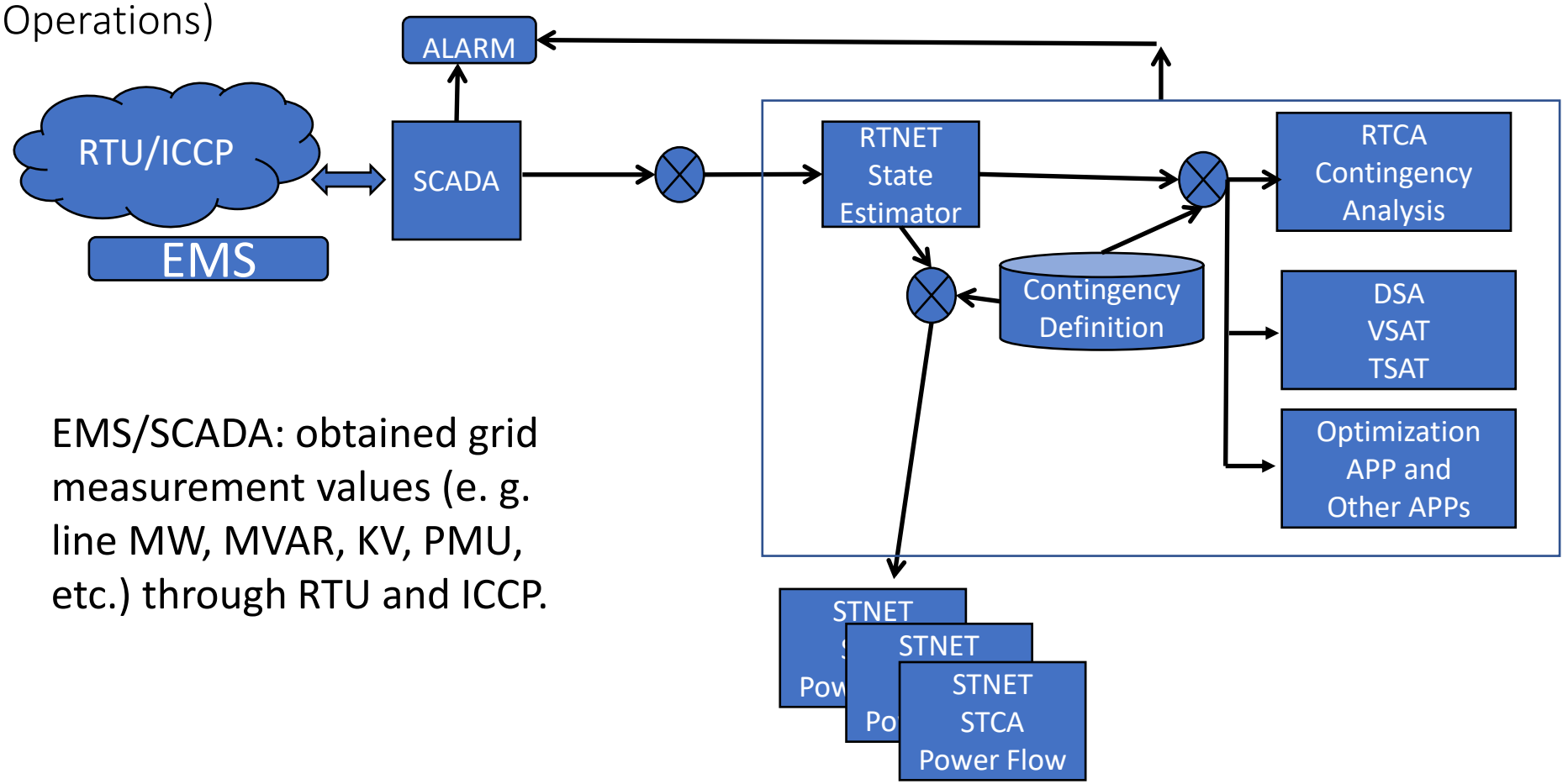
Input from the industry members and other reviewers does not constitute an endorsement of this report or its contents. Further, the views expressed herein do not necessarily represent the views of DOE or the U.S. Government. The authors take sole responsibility for the contents of this report.

Wind

EMS: SCADA and Advanced Applications

-SCADA (Real-Time Monitoring, Switching, Operations) and
-Advanced Applications (Real-Time Monitoring. Studies, Analysis, Studies, Planning and Operations)



EMS/SCADA: obtained grid measurement values (e. g. line MW, MVAR, KV, PMU, etc.) through RTU and ICCP.

EMS/Advanced Applications:
Power Grod Operations Generative AI

Q & A

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