California ISO Operational Experience with Inverter Based Resources

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California ISO roles

For much of the western U.S., the ISO:

- Operates the Western Energy Imbalance Market (EIM)
- Serves as Reliability Coordinator (RC West)
- **Balancing Authority for most of California**

Within its balancing authority area, the California ISO:

- Maintains reliability on the grid
- Manages the flow of energy
- Oversees the transmission planning process

California ISO Balancing Authority (BA) facts

As a federally regulated nonprofit organization, the ISO BA manages the high-voltage electric grid of California and a portion of Nevada.

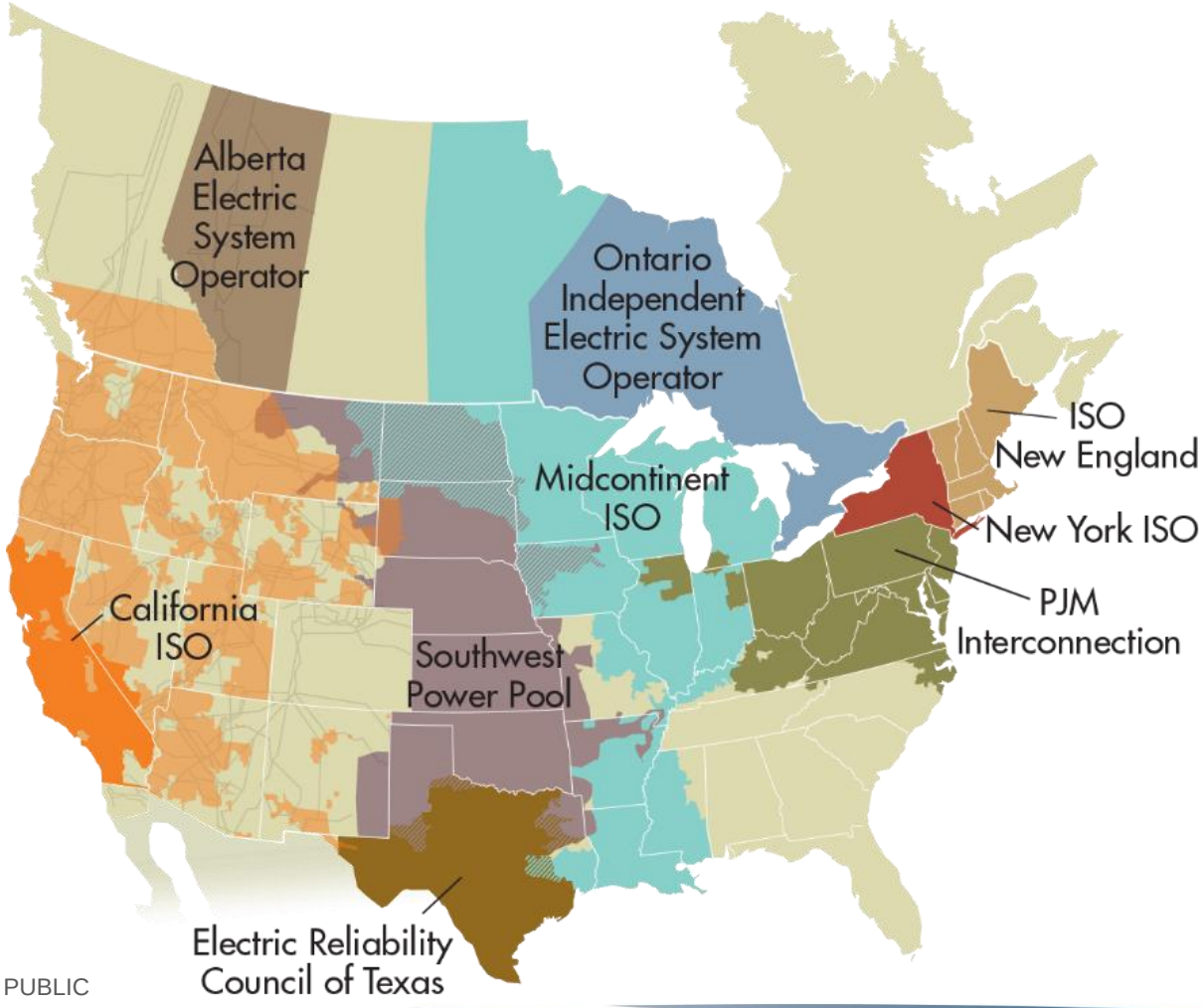
One of **9** ISO/RTOs in North America

32 million consumers served

52,061 MW record peak demand on Sept. 6, 2022

76,184 MW power plant capacity
Source: ISO's Masterfile, August 2023

1,119 power plants
Source: California Energy Commission



California ISO BA facts

26,000 circuit-miles of transmission lines

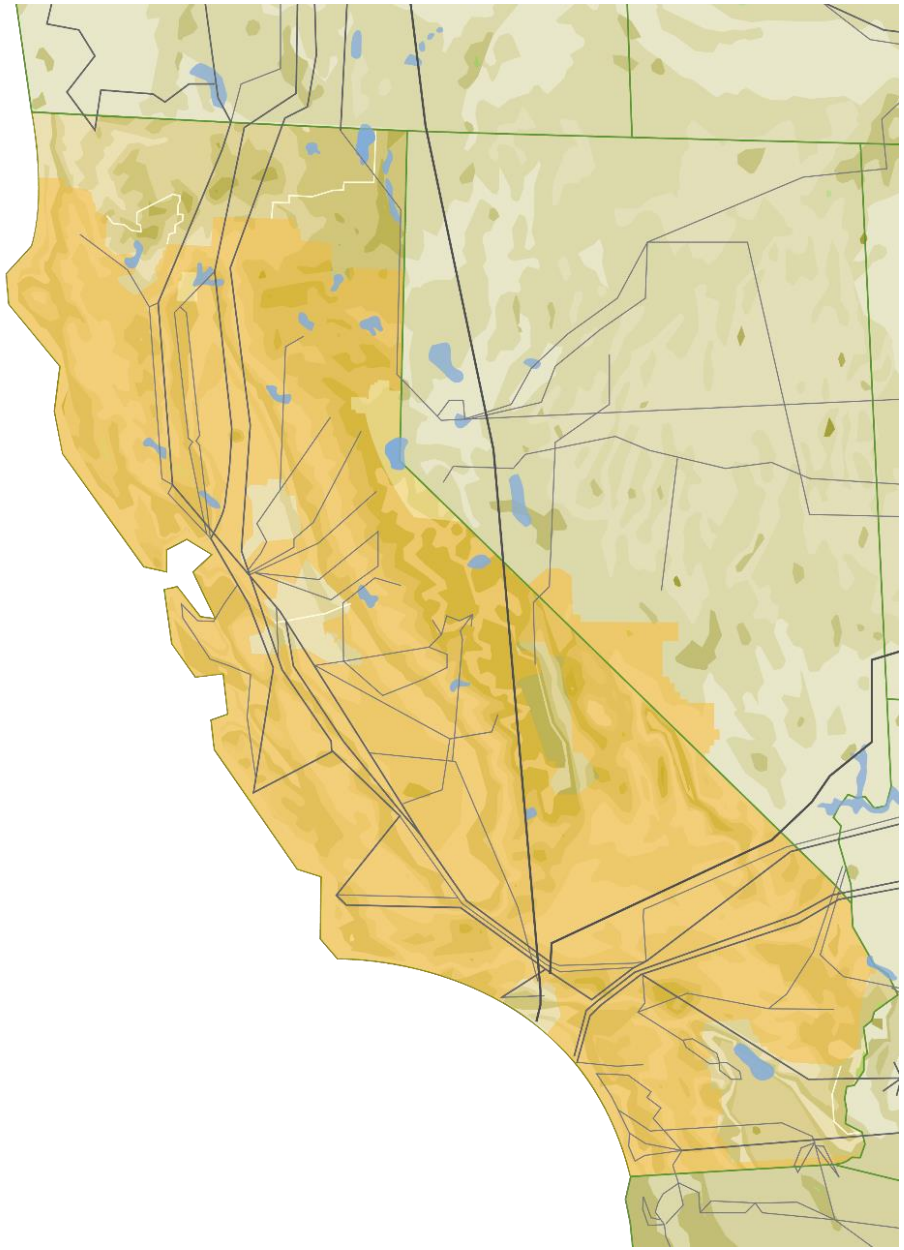
Renewable generation capacities

19,674 MW Solar
8,350 MW Wind
1,610 MW Geothermal
1,141 MW Small hydro
778 MW Biofuels

31,553 Total

10,219 MW battery capacity

(as of 10/01/24)



Historical statistics and records *(as of 10/08/2024)*

Solar peak

19,650 MW

Aug. 23, 2024 at 12:10 p.m.

Previous record:

19,368 MW, June 20, 2024

Wind peak

6,465 MW

May 28, 2022 at 5:39 p.m.

Previous record:

6,265 MW, March 4, 2022

Peak net imports

11,894 MW

Sept. 21, 2019 at 6:53 p.m.

Peak demand

52,061 MW

Sept. 6, 2022 at 4:57 p.m.

Second highest:

50,270 MW, July 24, 2006

Steepest 3-hour average ramp

21,505 MWh

Feb. 10, 2024 starting at 3 p.m.

Second highest:

21,153 MWh, Jan. 7, 2024

CAISO BA operational challenges

Large solar output displacing other resource types

- ✓ Sufficient ramp rate from resources to replace solar
- ✓ Storage is helping reduce belly of duck curve and replace solar

Reduced frequency response with reduction of spinning inertia

- ✓ Program IBR to respond similar to thermal/hydro units

Not following dispatch & incorrect ramping

- ✓ Increase awareness of resource behavior to grid stability

Unable to control resource

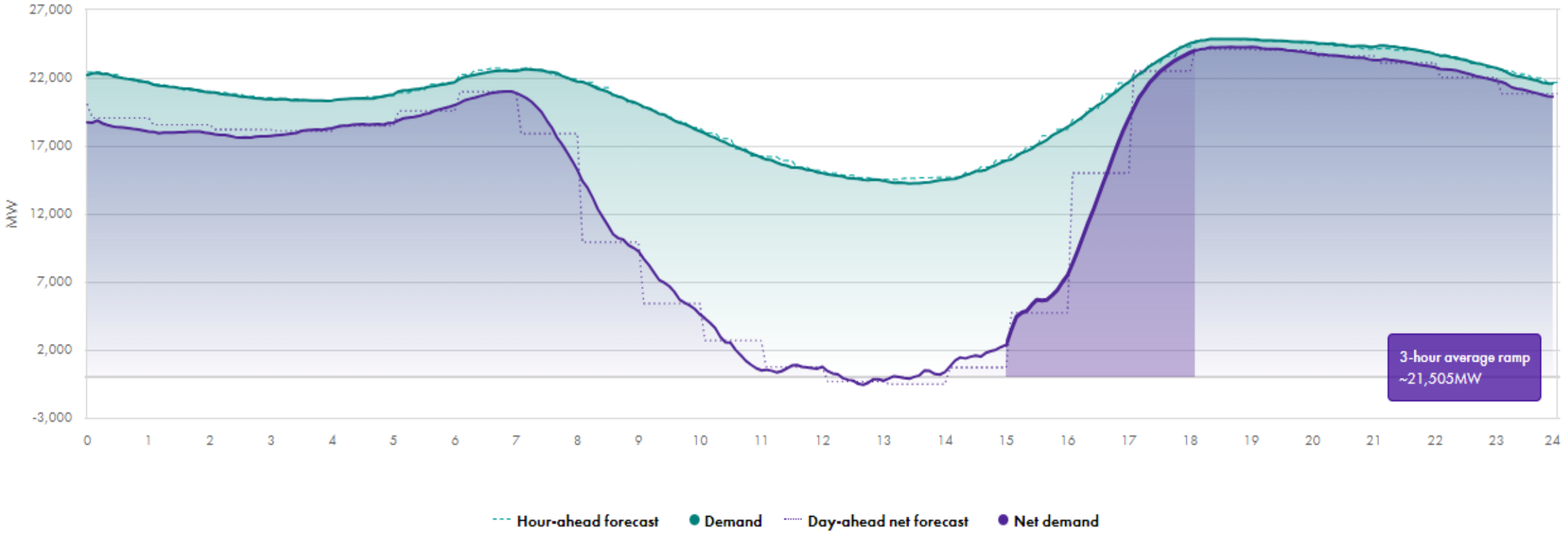
- ✓ Clearly communicate requirements to developer **and** operator

Incorrect inverter settings (cessation)

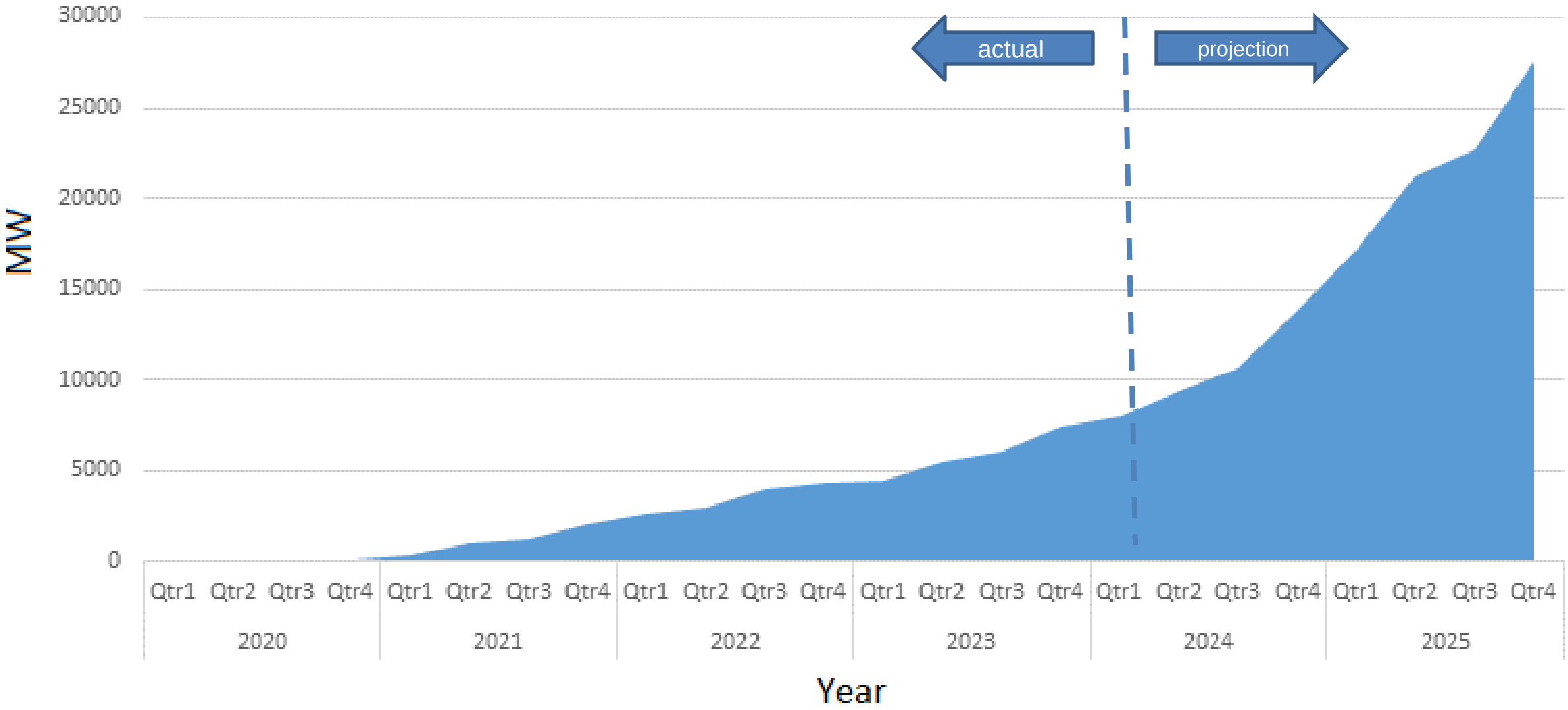
- ✓ reprogram IBR controllers and procure additional operating reserves

Gross Demand & Net Demand (gross minus solar & wind output)

Demonstrates flexible ramp capacity needed from other resources to coordinate with the solar ramp in the morning and evening hours

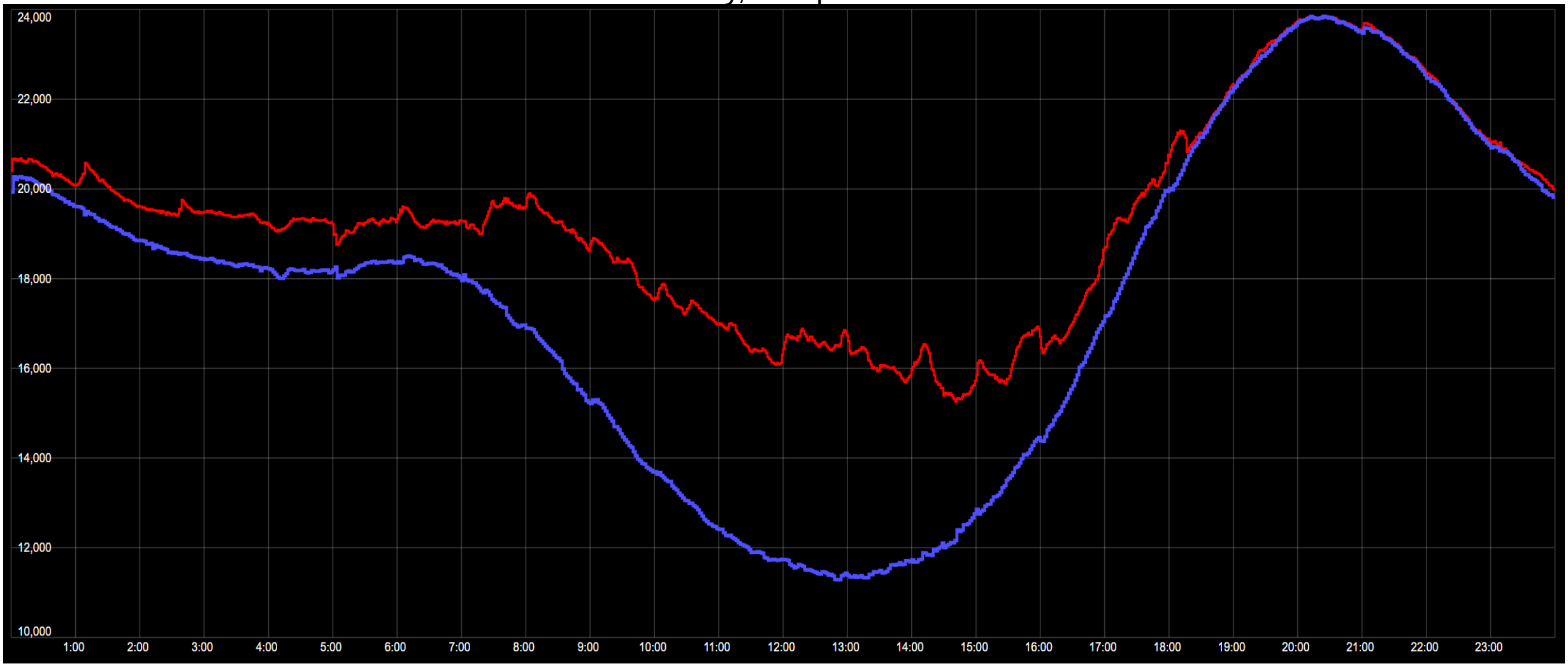


Battery storage installed in CAISO BA since 2020

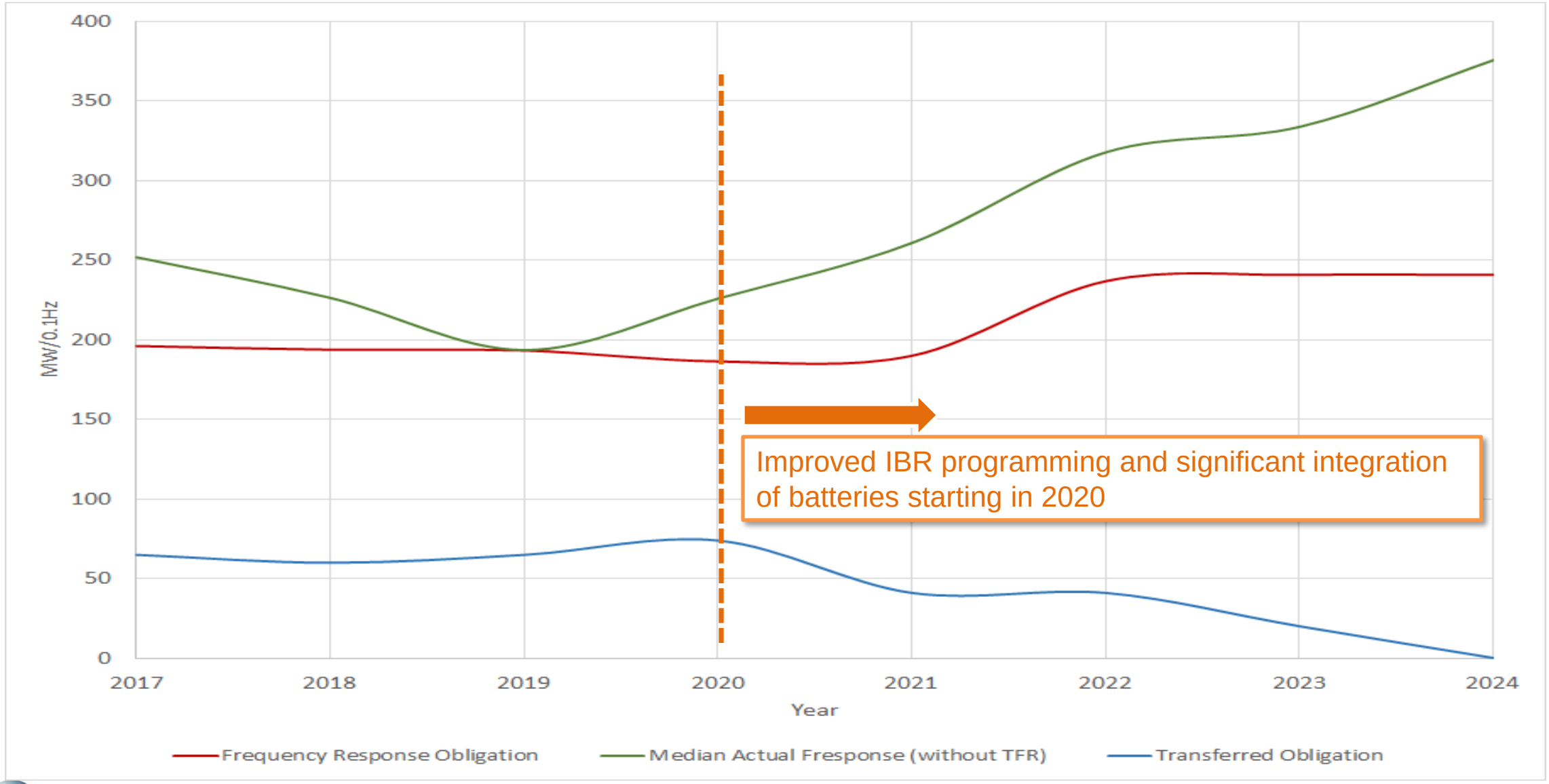


CAISO duck curve has flattened, reducing required ramping

Sunday, 28 April 2024



CAISO Frequency Response has improved



Challenges remain in the power grid evolution

Record setting number of new resources requesting to connect

- Requires revamp of interconnection study process
- Dramatic increase in manual data processing
- Accommodate testing of new resources

Transmission upgrades required for many of the new resources

- Time and money required
- Slower more complex process than adding new resources

Unfamiliarity with electric power operations

- Many owners are financial institutions
- Unaware of impact of uncoordinated testing
- Train developer on proper operation but once commercial operation is turned over to owner/scheduling coordinator
- Many sites operated remotely

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