Welcome To The Large Loads Task Force (LLTF) Kickoff Meeting

NERC Antitrust Compliance Guidelines, Public Meeting Notice, Participant Conduct Policy, Introductions, and Safety Briefing.

Opening Remarks

Matthew Veith, Director Realtime Reliability Eng - American Electric Power
Agee Springer, Sr. Manager, Grid Interconnections - ERCOT
Vinit Gupta, Vice President of Operations - ITC Holdings Corp
Latrice Harkness, Director of Engineering - NERC

LLTF Kickoff Meeting
October 8, 2024

Large Loads Task Force Work Plan Review

Marilyn Jayachandran, Manager, Advanced System Analytics & Modeling - NERC
LLTF Kickoff Meeting
October 8, 2024

LLTF Work Plan

- White Paper: Characteristics and Risks of Emerging Large Loads
  - White Paper on the unique characteristics and risks associated with emerging large loads. This paper will leverage the NERC Framework to address known and emerging reliability and security risks to identify, validate, and prioritize potential reliability risks related to the integration of emerging large loads
    - Target Completion: Q2 – 2025
- White Paper: Assessment of Gaps in Existing Practices, Requirements, and Reliability Standards for Emerging Large Loads
  - White Paper assessing whether existing engineering practices, requirements, and Reliability Standards can adequately capture and mitigate reliability impact(s) of large loads interconnected to the BPS. The paper will also highlight gaps in load modeling practices that LMWG can leverage to take further action to improve load modeling
    - Target Completion: Q2 – 2025
- Reliability Guideline: Risk Mitigation for Emerging Large Loads
  - Reliability Guideline identifying risk mitigation including improvements to existing planning, and operation processes and interconnection requirements for large loads. Guidance may include recommended improvements to modeling practices, analyses, coordination and data collection efforts, real time monitoring and event analysis
    - Target Completion Q2 – 2026

Questions and Answers

Keynote Address

David Ball, Senior Vice President Energy Delivery – American Electric Power
LLTF Kickoff Meeting
October 8, 2024

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY℠

Planning and Operating the Grid of the Future

Large Data Centric Flexible Load Operational Impact Review

BOUNDLESS ENERGY℠

AMERICAN ELECTRIC POWER

BOUNDLESS ENERGY℠

Energy Delivery Overview

The Energy Delivery organization is responsible for engineering, maintaining, and operating AEP's Transmission grid and field telecommunications leased and owned network equipment. AEP is the largest Transmission Owner in North America with over 40,000 miles of transmission lines and 4,000 substation facilities. Energy Delivery works in close collaboration with Operating Companies and other Energy Services groups to make certain all grid-related risks are properly managed. Additionally, because of the very critical nature of the grid to the U.S., there are rigorous standards and regulations that require very strict compliance (e.g., cyber and physical protection) to ensure that utilities "keep the country's lights on." Approximately 70% of the NERC standards applicable to AEP fall under the responsibility of Energy Delivery, and to ensure the organization meets the demands of this responsibility, Energy Delivery works very closely with experts across AEP to achieve the highest standards of assurance, compliance, and documentation management.

David Ball

Senior Vice President

Employees: 2,972,

~ 3,000 Outsource contractor employees

2024 Control Budget:

- O&M*: $280M
- Break and Fix Capital: $350M
- Transmission Capital Support: $4.3B

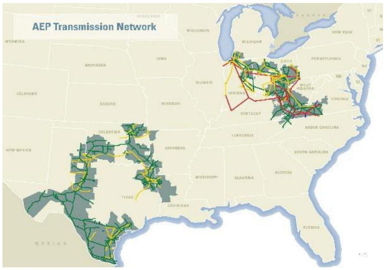
Key Initiatives:

- Proactive Safety Leadership
- Cultural Excellence
- Lower per unit cost
- Investment flexibility
- Manage Grid Reliability / Security
- Expedite Response

* Includes Non-Earnings Offset O&M and Earnings Offset O&M

Engineering

Responsible for all internal and external engineering standards associated with AEP grid assets. Also, accountable for all internal and external engineering deliverables associated with the overall Transmission ~$3B capital portfolio.



Telecom Field Services

Responsible for AEP-owned and/or leased field assets associated with AEP owned and operated networks. This includes commissioning, maintenance, and emergency response. AEP networks are key to real time operational tools, as well as corporate business tools, highlighting the criticality of this team to AEP.

Transmission Field Services

Responsible for maintaining existing Transmission equipment, commissioning new equipment, setting and monitoring thousands of protection, control, and monitoring devices, as well as overseeing the forestry program for Transmission. There are over 2,200 substations, 60,000 devices, and 40,000 line miles to monitor and maintain. Additionally, this team holds the critical responsibility of storm response.

Real Time Operations (Response and Reliability)

AEP Transmission has a very large presence in each of the Regional Transmission Operator footprints that we serve. The Real Time Operations team is responsible for the real time assessment, monitoring, and control of thousands of Transmission assets (e.g., circuit breakers, switches, voltage control devices) essential to "keeping the lights on" in each of these regions. This area of our business is heavily regulated, and compliance is critical to success.

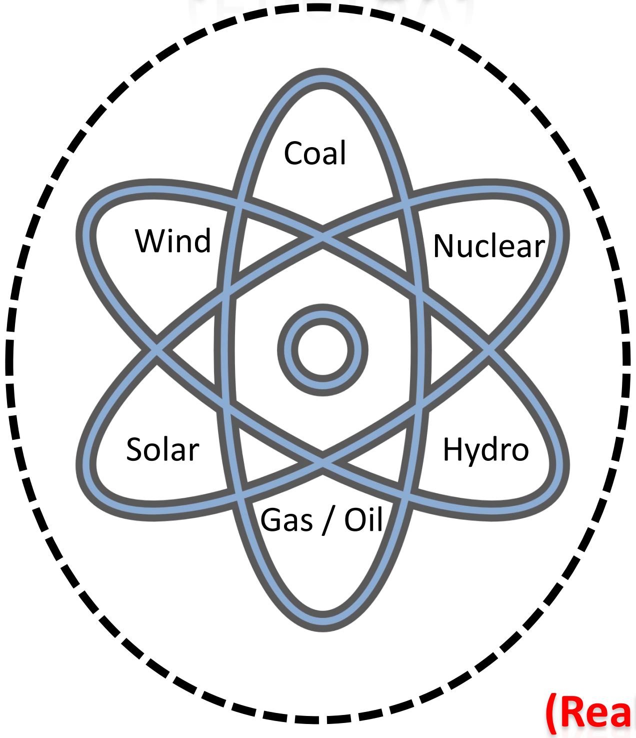
Support

Accountable for all documentation across Energy Delivery, for initial and continuing education training for transmission system operators, and for ensuring the system-wide strategy, coordination, and technical support for all Energy Delivery NERC, FERC, and State and Federal compliance standards and controls.

Large Load Risk

Large Data Centric Flexible Loads (LDCFL) in an area intentionally or unintentionally cycle in a way that creates a modal frequency in the grid that cannot be identified to the source in a timely manner, thus causing the grid to begin "self-isolation." The isolation may be at an area, zone, or interconnection level depending on the number of LDCFLs contributing to the oscillation.

Generation
(Energy)



Plan & Operate
~ (Frequency)
V (Voltage)
Rating (Thermal)

Demand
(Customer)

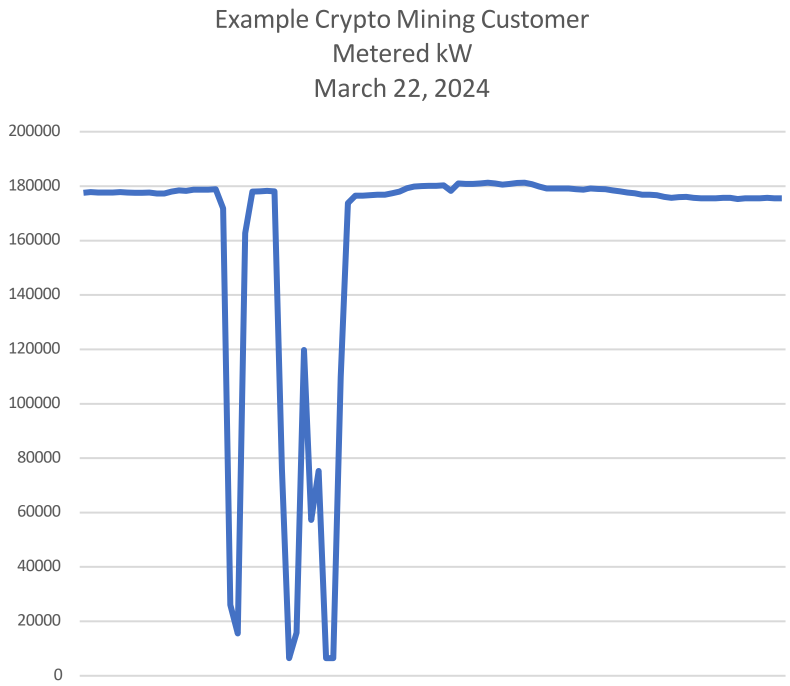
Transmission

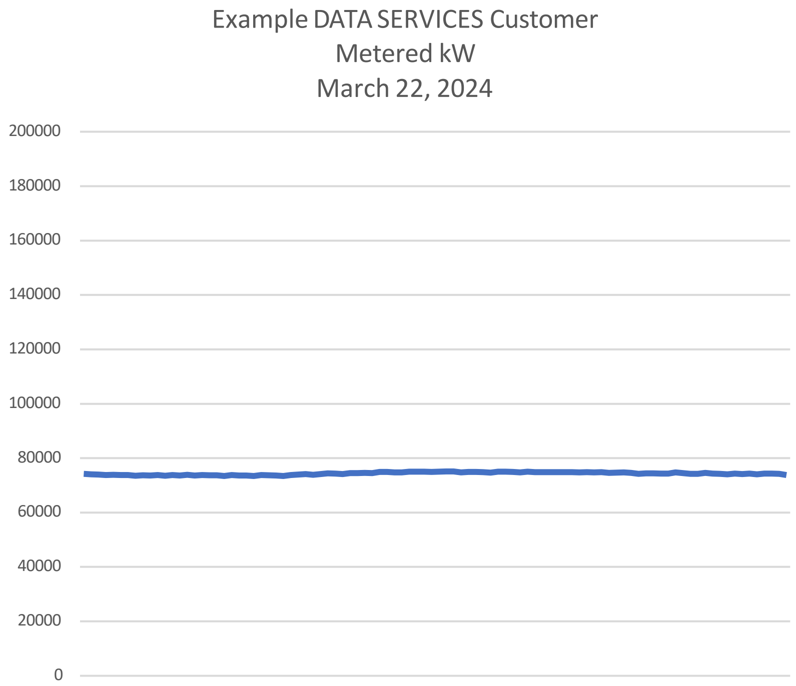
(Planning Analysis Tools)
(Real Time Situational Awareness Tools)
REQUIRE AN ACCURATE CONNECTIVITY MODEL
The model must represent the in-service grid assets

NERC Registration Examples

- **Balancing Authority (BA**) - The responsible entity that integrates resource plans ahead of time, maintains Demand and resource balance within a Balancing Authority Area, and supports Interconnection frequency in real time.
- **Reliability Coordinator (RC)** - The entity that is the highest level of authority who is responsible for the Reliable Operation of the Bulk Electric System, has the Wide Area view of the Bulk Electric System, and has the operating tools, processes and procedures, including the authority to prevent or mitigate emergency operating situations in both next-day analysis and real-time operations. The Reliability Coordinator has the purview that is broad enough to enable the calculation of Interconnection Reliability Operating Limits, which may be based on the operating parameters of transmission systems beyond any Transmission Operator's vision.
- **Transmission Operator (TOP)** -The entity responsible for the reliability of its "local" transmission system, and that operates or directs the operations of the transmission Facilities.
- **Generator Operator (GOP)** - The entity that operates generating Facility(ies) and performs the functions of supplying energy and Interconnected Operations Services.

Example Crypto Mining Customer vs. Example DATA SERVICES Customer





BOUNDLESS ENERGY℠

Industry Risk Mitigation

Order aligns with urgency:

1. Formal registrations of all Large Fixed Loads (LFL) that spell out ownership, operating entity, and current/updated business purpose
2. Planning tools that allow the planning teams, prior to approving the connection, to fully analyze the risks associated with capacity servicing LFLs and the intentional/unintentional cycling of LFL connections
   - Management of the development to ensure there is no malware baked into the tool (We suggested National Lab for security management)
3. Real time operational tools that allow the real time teams to perform dynamic stability analysis in real time with functionality that allows for quick identification of system oscillation triggers (Generation or Demand) and suggested actions to remove triggers from the grid in real time.
   - Management of the development to ensure there is no malware baked into the tool (We suggested National Lab for security management)
4. Verified **isolation** of the LFL operational systems from the connected TOP/TO real time operational tools

Note: The term Large Fixed Load is an internal Energy Delivery Term. If a significant number of these connect in the same area, they could change the load curve to appear flat or near flat over the entire 24-hour period that we currently manage to in the day ahead and real time horizons.

Appendix / Reference Material

Example RTO

Generation
(Energy)

Coal

Wind

Nuclear

100,000 MW

Solar

Hydro

Gas / Oil

Plan & Operate

~ (Frequency)

V (Voltage)

Rating (Thermal)

=

Demand
(Customer)

100,000 MW

Transmission

(Planning Analysis Tools)

(Real Time Situational Awareness Tools)

REQUIRE A CONNECTIVITY MODEL

The model must represent the in-service grid assets

AMERICAN ELECTRIC POWER
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Example RTO

Generation
(Energy)

Coal

Wind

Nuclear

110,000 MW

Solar

Hydro

Gas / Oil

Plan & Operate

~ (Frequency)

V (Voltage)

Rating (Thermal)

=

Transmission

(Planning Analysis Tools)

(Real Time Situational Awareness Tools)

REQUIRE A CONNECTIVITY MODEL

The model must represent the in-service grid assets

Demand
(Customer)

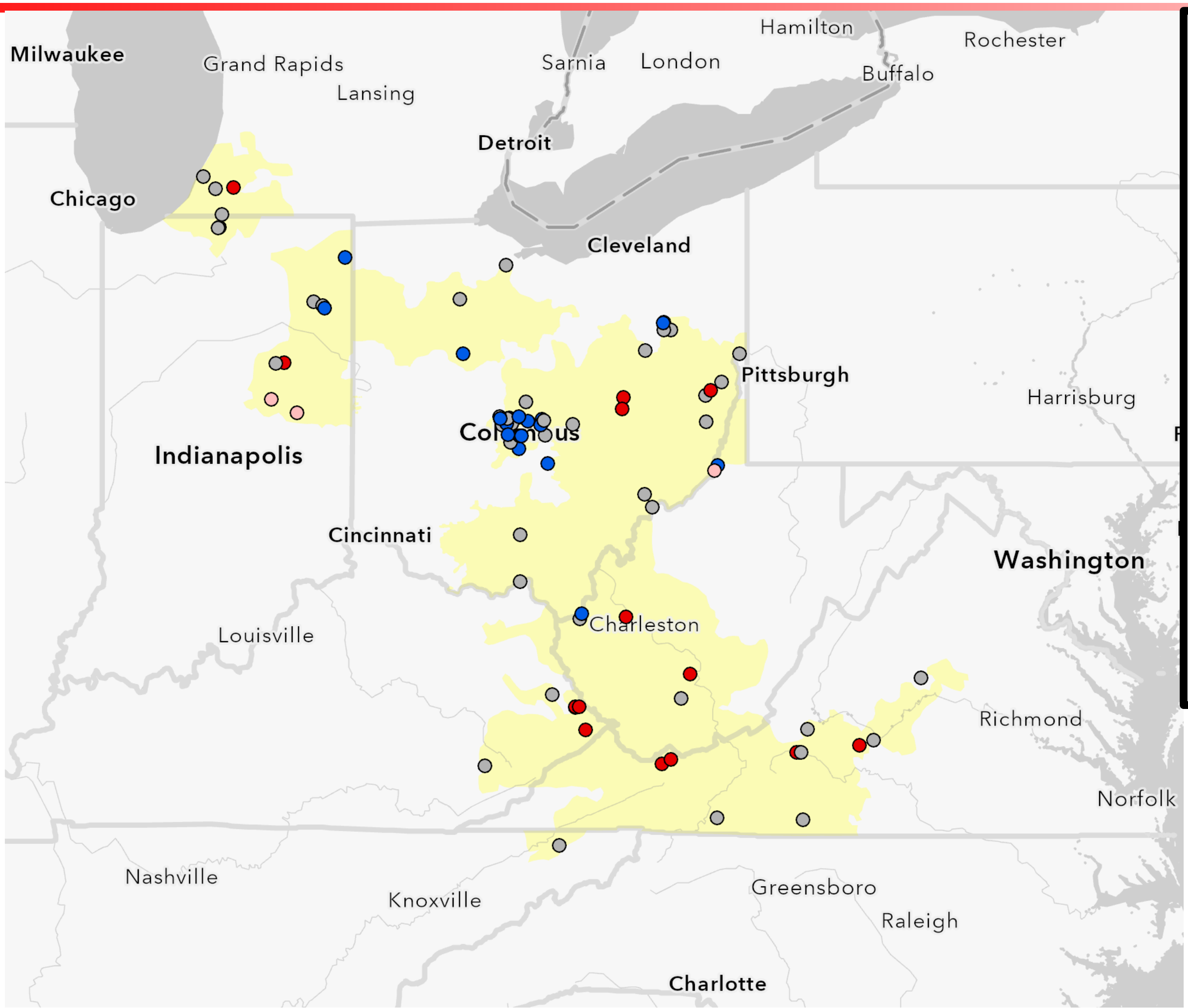
110,000 MW

Utility X

10,000 MW Traditional

+ 10,000 MW LFL

Peaks – PJM

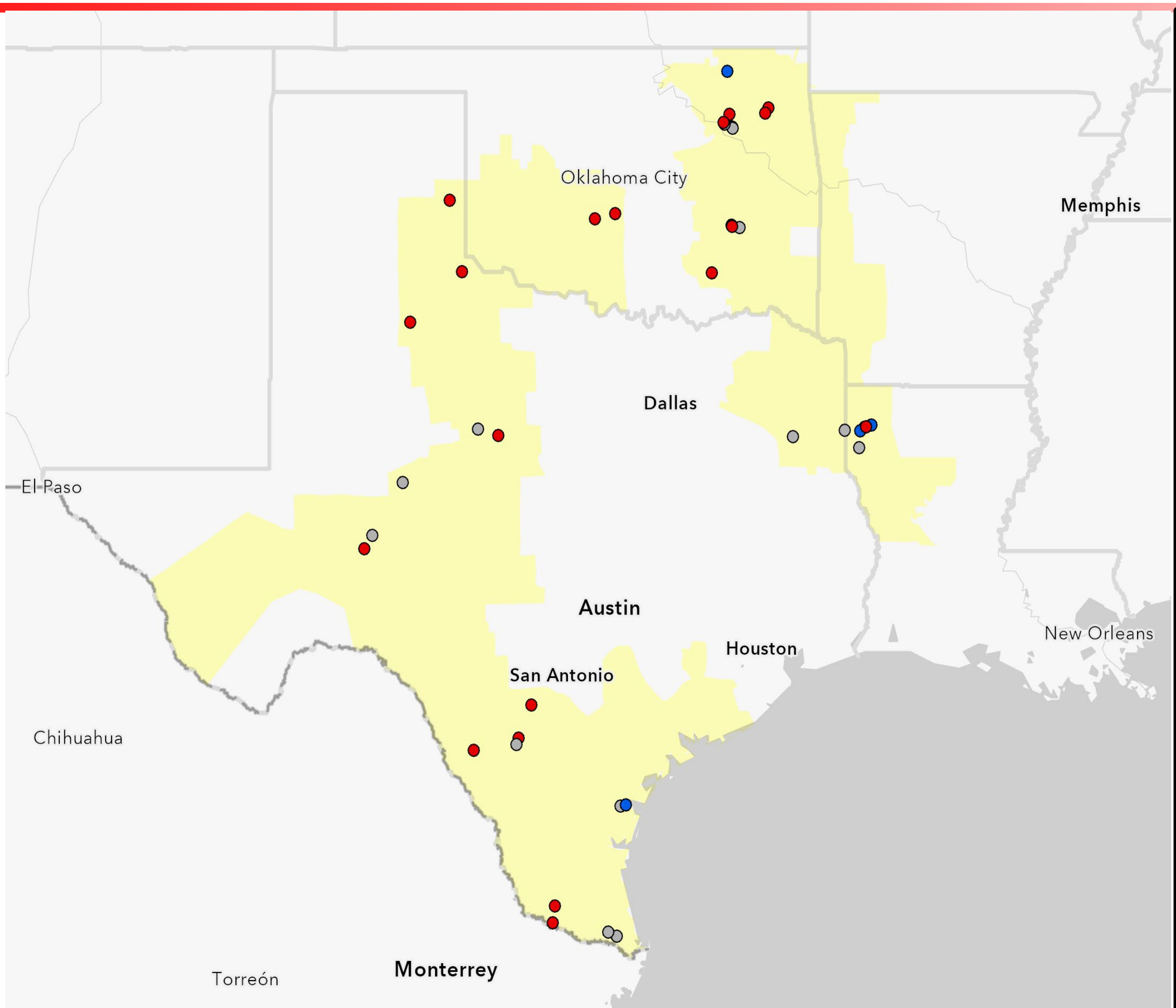


PJM
Winter Peak = 155,709 MW
Summer Peak = 137,866 MW

AEP (PJM Area)
Winter Peak = 22,776 MW
Summer Peak = 22,407 MW

Ohio = 8,100 MW
ApCo = 6,000 MW
WP = 690 MW
I&M = 3,970 MW
KP = 1,084 MW

Peaks – SPP and ERCOT



<u>SPP</u>
Winter Peak = 47,157 MW
Summer Peak = 56,184 MW

<u>AEP (SPP Area)</u>
Winter Peak = 6,784 MW
Summer Peak = 8,081 MW

SWEPCO = 4,886 MW
PSO = 4,287 MW

<u>ERCOT</u>
Winter Peak = 78,314 MW
Summer Peak = 85,508 MW

<u>AEP (ERCOT Area)</u>
Winter Peak = 7,405 MW
Summer Peak = 7,432 MW

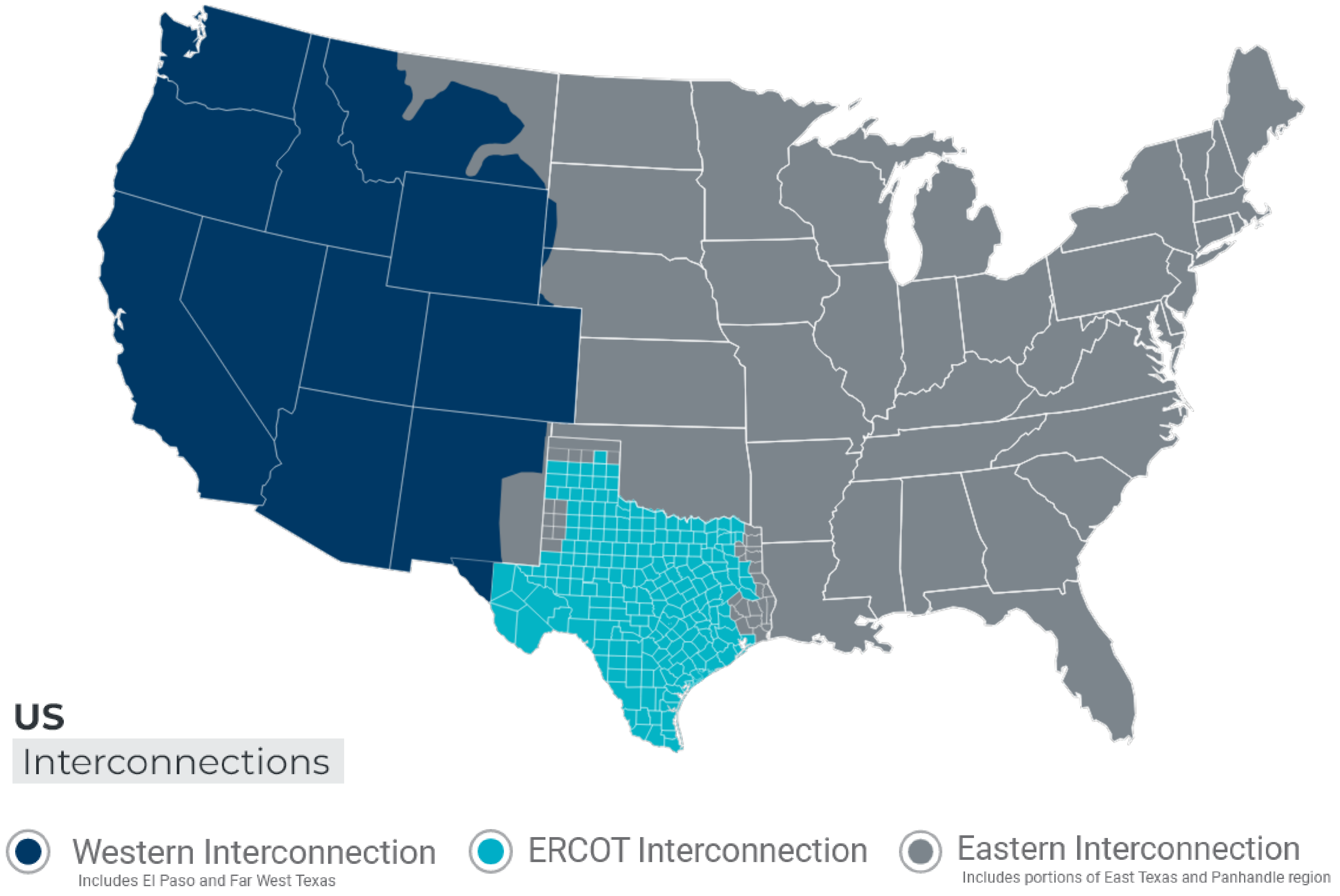
TCC = 5,972 MW
TNC = 2,006 MW

Large Loads in ERCOT – Observations and Risks to Reliability

Agee Springer
Sr. Manager, Grid Interconnections

NERC Large Load Task Force
October 8, 2024

The ERCOT Region



The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 85,508 MW peak, August 10, 2023
- More than 54,100 miles of transmission lines
- 1,250+ generation units
  (including Private Use Networks)

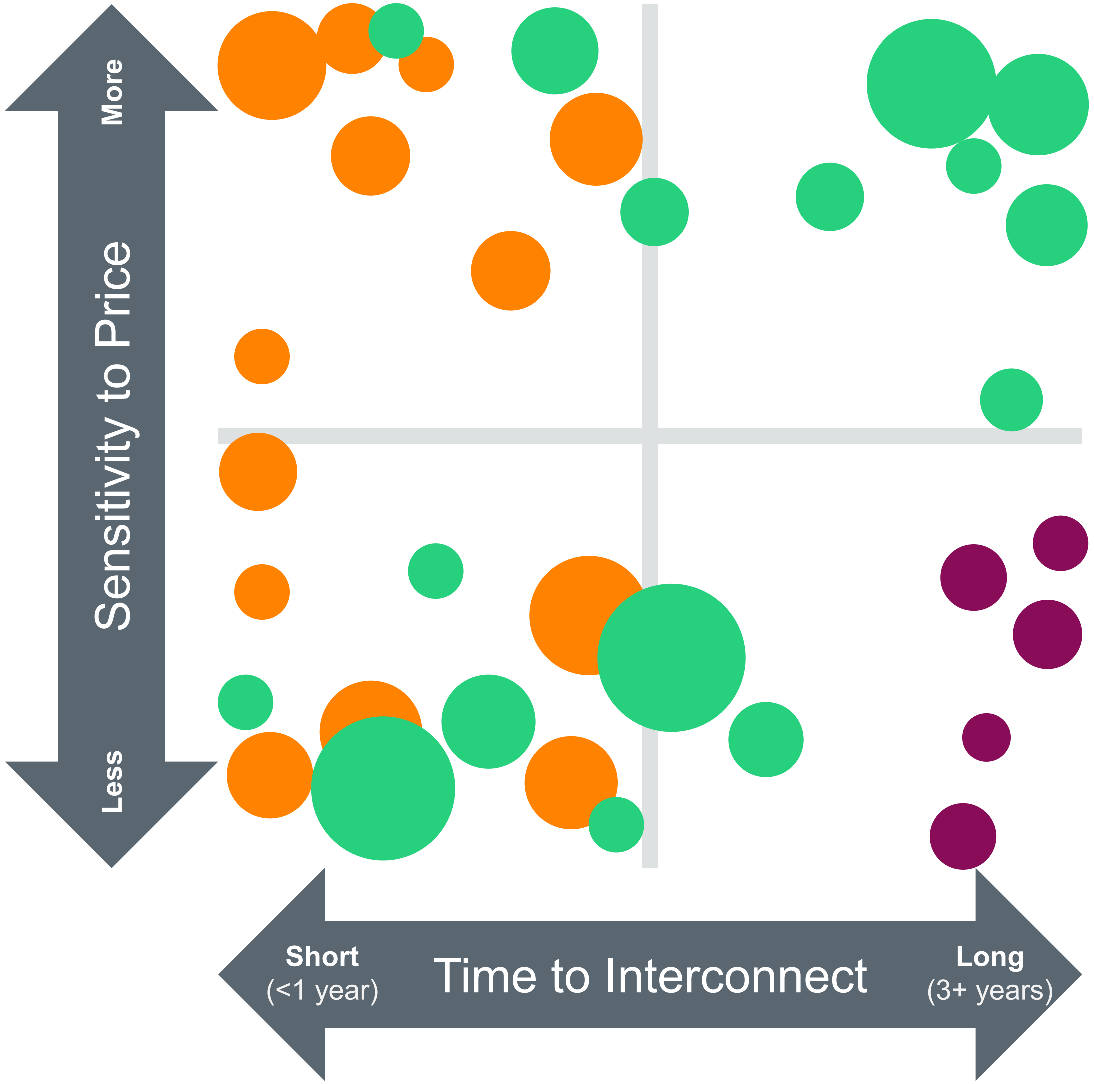
ERCOT connections to other grids are limited to ~1,220 MW of direct current (DC) ties, which allow control overflow of electricity

Large and Flexible Loads - Definitions

- ERCOT considers a site with an aggregate Load of 75 MW or greater behind a one or more points of interconnection to be a **Large Load**

- ERCOT considers a Load that can raise or lower its consumption in response to wholesale prices or other grid conditions to be a **flexible Load**
  - Some flexible Loads are registered with ERCOT as Load Resources and provide Ancillary Services and/or participate in the Security Constrained Economic Dispatch (SCED)
  - Many other flexible Loads adjust consumption independent of any direction from or coordination with ERCOT

Changing Characteristics of Large Loads Coming to ERCOT



Historical Large Loads

- Typically industrial facilities
- Long timelines to interconnect can be studied by traditional planning processes
- Little price-sensitive behavior in real-time

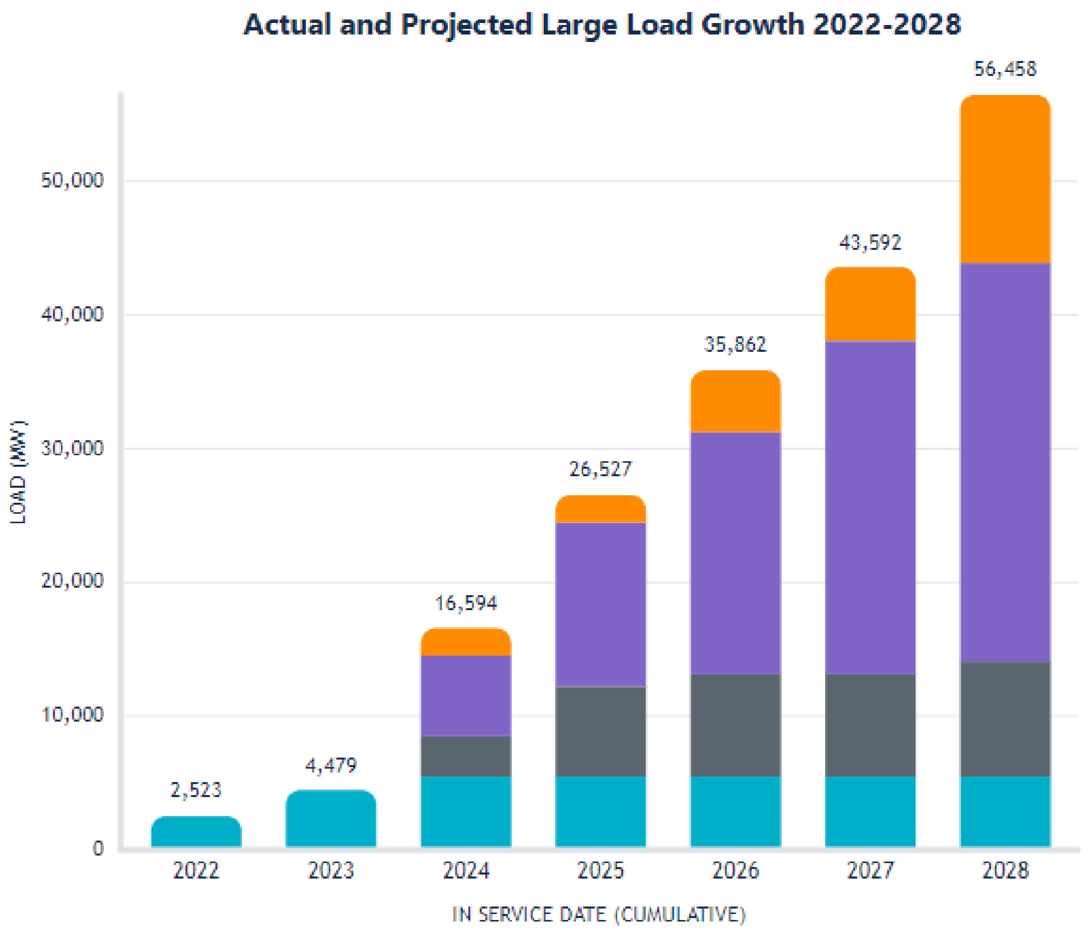
Current Wave of Large Loads

- Mostly cryptomining, data centers (traditional and AI), some oil field Load
- Much shorter timeline to interconnect (months rather than years)
- Some Loads are extremely sensitive to price

Projected Future Large Loads

- Hydrogen/electrofuel production, AI data centers, some cryptomining
- Range of interconnection timelines and price sensitivity

Tracking Large Loads with Short Timelines to Interconnect



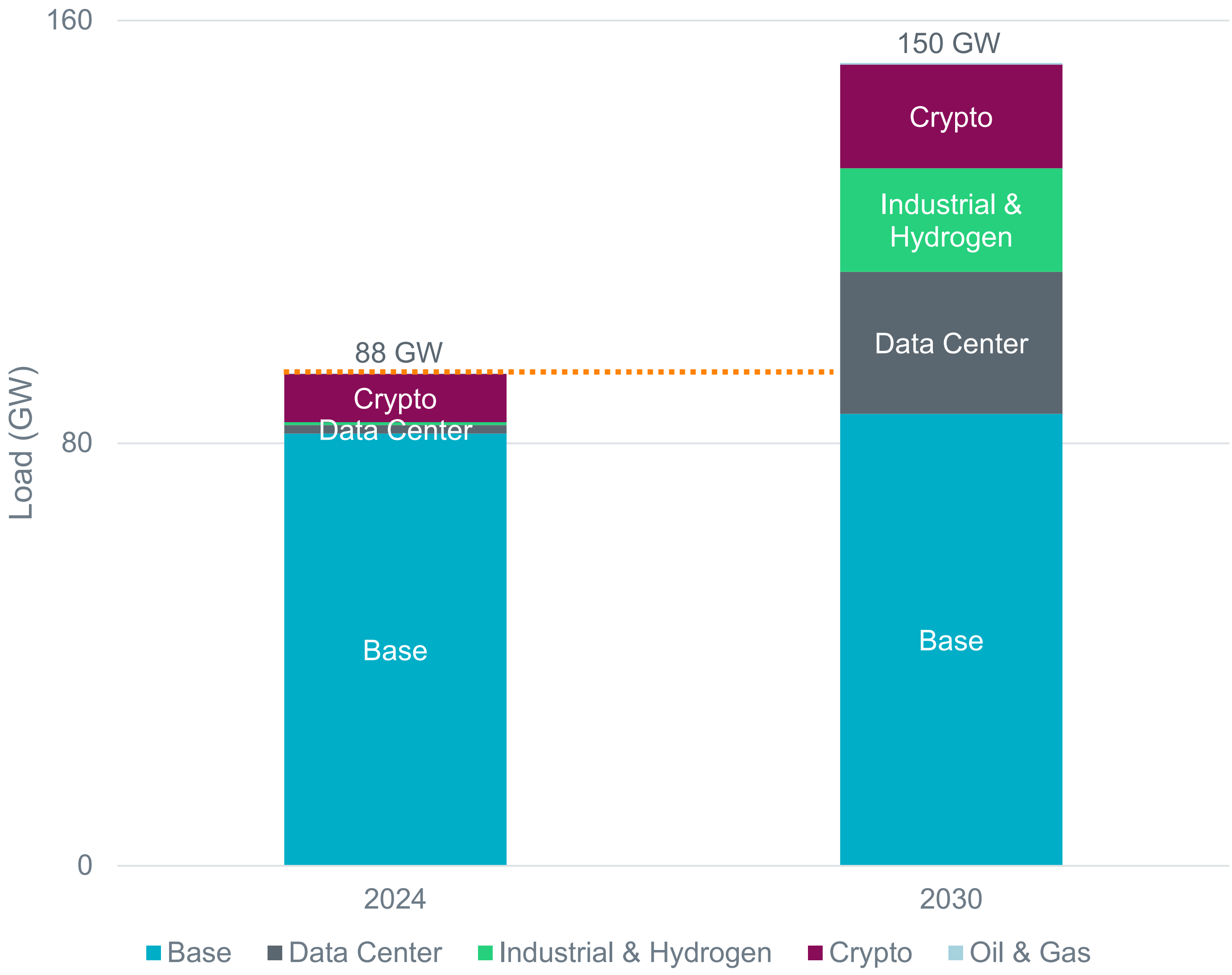
Project Status	2022	2023	2024	2025	2026	2027	2028
No Studies Submitted	-	-	2,040	2,040	4,640	5,540	12,582
Under ERCOT Review	-	-	6,077	12,276	18,087	24,917	29,782
Planning Studies Approved	-	-	2,981	6,715	7,639	7,639	8,598
Approved to Energize	2,523	4,479	5,496	5,496	5,496	5,496	5,496
Total (MW)	**2,523**	**4,479**	**16,594**	**26,527**	**35,862**	**43,592**	**56,458**

- **Approved to Energize –** Projects that have received Approval to Energize from ERCOT Operations. NOTE: not all MWs in this category have been observed to be operational (see next slide)
- **Planning Studies Approved –** Projects that have received ERCOT approval of required interconnection studies. Any MWs that were not approved are reclassified as No Studies Submitted.
- **Under ERCOT Review –** Projects that have studies under review by ERCOT
- **No Studies Submitted –** Projects that are tracked by ERCOT but that have not yet provided sufficient information for ERCOT to begin review. Additionally, MWs that were not approved by ERCOT after review of planning studies are included in this category until a path to interconnect these MWs is identified or the customer cancels the interconnection request.

This chart does **not** include all large load projects with longer interconnection timelines (such as most hydrogen/electrofuels projects)

New Load Growth in the ERCOT System: 2024 - 2030

- Previous Regional Transmission Plan (RTP) rules did not allow ERCOT to factor in load without a signed interconnection agreement.
- House Bill (HB) 5066 (88th Legislative Session) required consideration of prospective load identified by Transmission Service Providers (TSPs) in grid planning.
- This led to significant increases in large loads considered in studies (*i.e.*, crypto mining, hydrogen and hydrogen-related manufacturing, data centers, and electrification).



Reliability Risks

- Short Interconnection Timelines
- Voltage Ride-Through and Interconnection Size
- Rapid Changes in Consumption
- Forecasting and Predictability
- Alignment of Market Design and Reliability

Reliability Risk – Short Interconnection Timelines

Reliability Risk

New types of Large Loads want to interconnect in less than 2 years. Traditional planning processes cannot prepare the grid to serve this new Load reliably.

- Traditional planning processes do not review this timeframe.
- Transmission upgrades needed to serve the full requested load amount often cannot be built in less than 2 years.
- All Load must be studied as firm – no concept of “flexible Load”

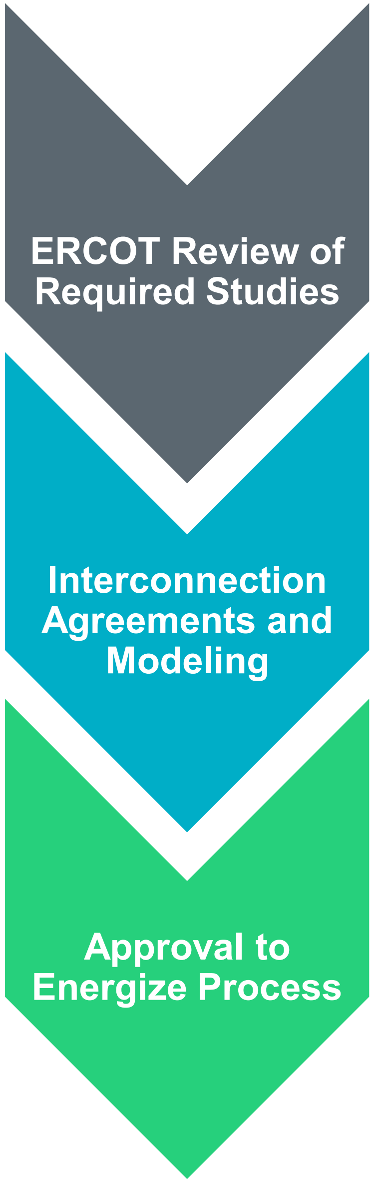
New Interconnection Process

- In March 2022, ERCOT implemented an **interim** interconnection process for Large Loads wishing to connect within 2 years or less

- This process
  - Ensures new interconnection requests are studied for reliability as required by NERC FAC standards
  - Identifies new transmission upgrades that are needed to serve the Load
  - Determines the amount of Loads that can be served **reliably** until transmission upgrades are in service and limits the demand to that amount

- ERCOT is proposing to formalize this process on adoption of NPRR1234 and PGRR115

- Additional Protocol changes proposed in NPRR1188 must be adopted before planned load can be studied as flexible



Large Load Interconnections – Remaining Questions

- With so many Loads wanting to connect quickly, how can construction of new transmission upgrades be expedited?

- Who bears the cost of these upgrades?

- What happens if the customer does not materialize or leaves within a few years?

- Will accounting for demand flexibility in grid planning mask the need for upgrades in some areas?

Reliability Risks

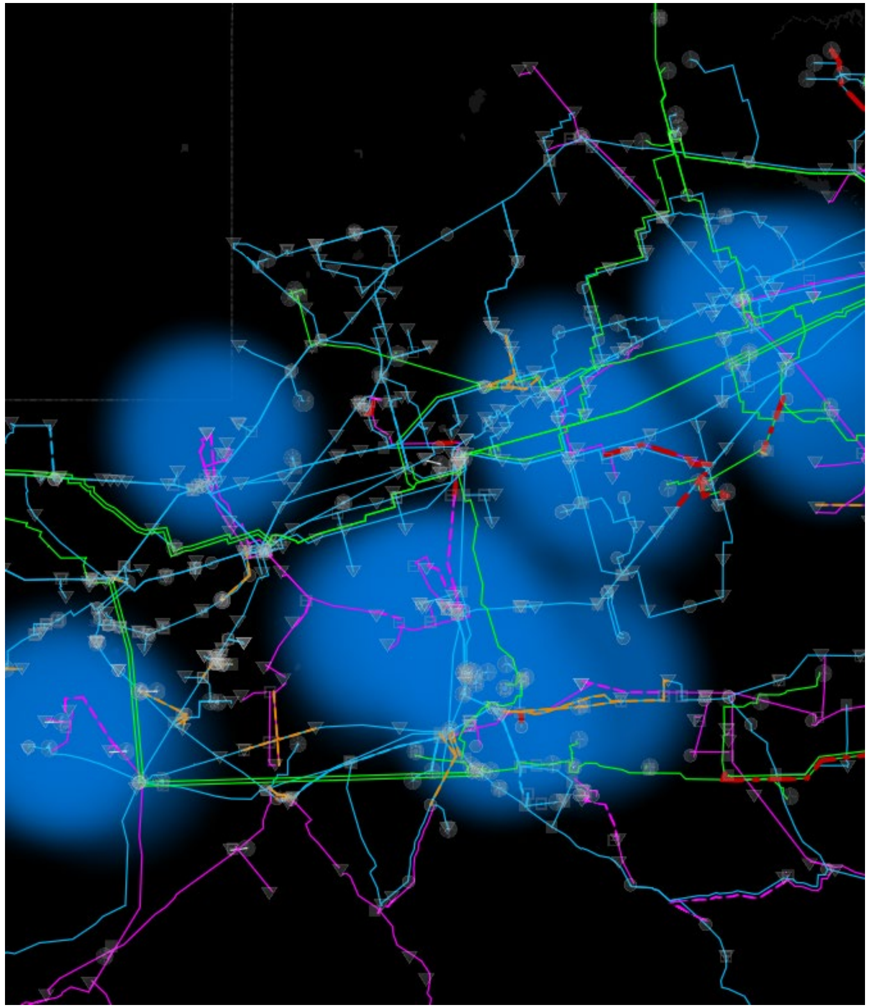
- Short Interconnection Timelines
- Voltage Ride-Through and Interconnection Size
- Rapid Changes in Consumption
- Forecasting and Predictability
- Alignment of Market Design and Reliability

Voltage Ride-Through (VRT) – Concept

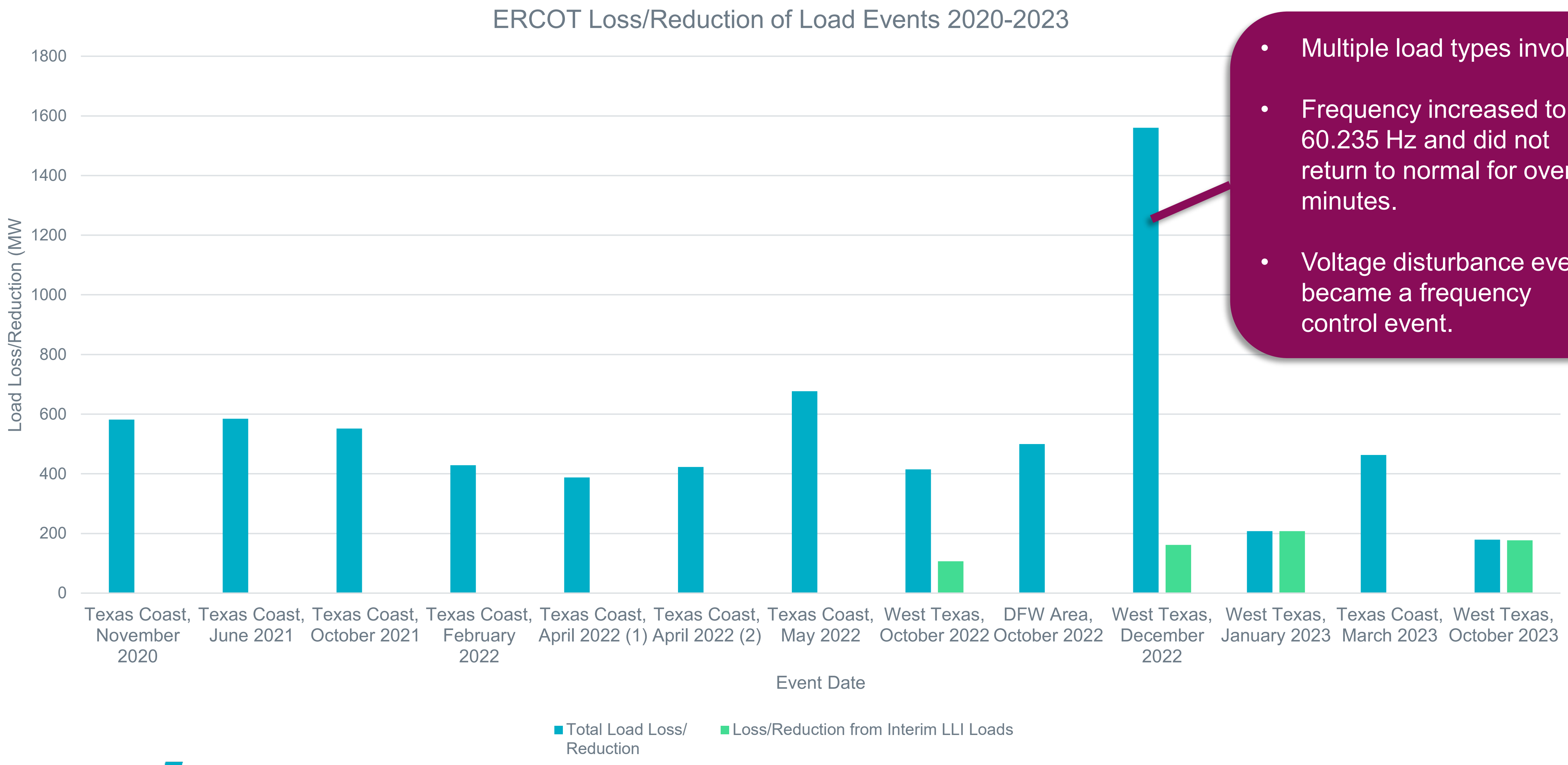
- When there is a fault on the system, voltage at the location of the fault will go to zero volts and voltage in the vicinity of the fault will be depressed

- Generators are required to remain connected to the grid (ride-through) during low-voltage events. The amount of time depends on the severity of the voltage drop.

- No such requirement currently exists for Loads.

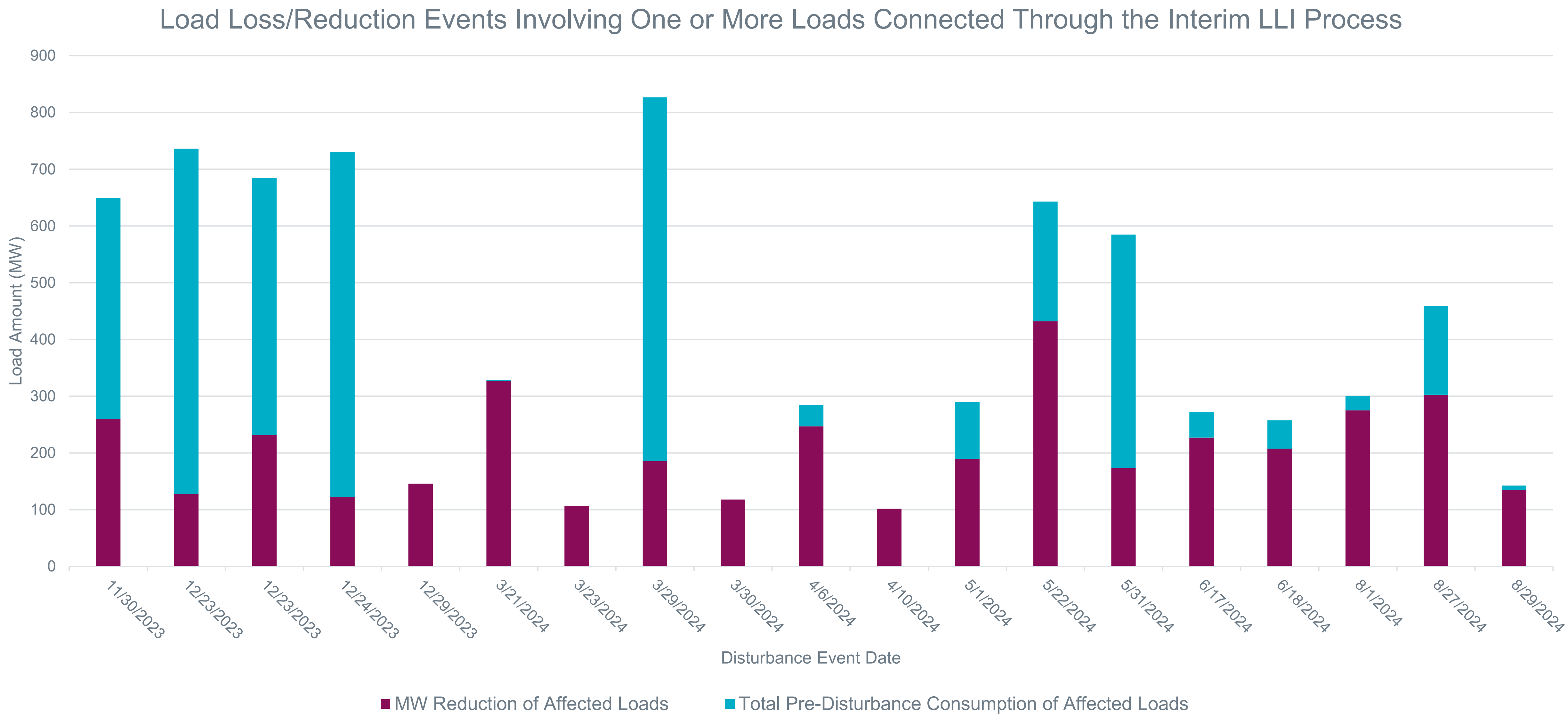


List of recent Voltage Ride-Through events



- Multiple load types involved
- Frequency increased to 60.235 Hz and did not return to normal for over 10 minutes.
- Voltage disturbance event became a frequency control event.

List of recent Voltage Ride-Through events



Reliability Risk – Voltage Ride-Through

Reliability Risk

Some load types are reducing consumption during voltage disturbance events. When these loads are large, this behavior can cause a significant and unexpected frequency disturbance.

- ERCOT has observed several new types of loads (variable frequency drives, datacenters/cryptomining) are particularly sensitive to voltage disturbances.
- Addressing this risk is challenging as historically some load reduction/ tripping during a fault/low voltage has been good for the system, particularly for loads that increase real or reactive power consumption at lower voltages
- But, as the amounts of voltage-sensitive loads increase and system strength decreases, the risk of large amounts (GWs) of load loss during a voltage disturbance increases

Approach 1 – Establish Voltage Ride-Through (VRT) Standard

One possible approach to mitigate this risk would be to require large loads to ride through certain fault conditions, much like IBRs. This approach comes with technical and operational challenges.

Table A

Root-Mean-Square Voltage (p.u. of nominal)	Minimum Ride-Through Time (seconds)
V > 1.20	May ride-through or trip
1.10 < V ≤ 1.20	0.5
0.90 ≤ V ≤ 1.10	Continuous
0.80 ≤ V < 0.90	2.0
0.70 ≤ V < 0.80	0.50
0.50 ≤ V < 0.70	0.20
V < 0.50	0.15

From ITIC Curve

Based on IEEE 1668 Single-Phase and Phase-Phase Curve

Based on ITIC Curve, but extended to ride-through fault duration

Table B

Instantaneous Phase-to-Phase or Phase-to-Ground Voltage (p.u. of nominal)	Minimum Ride-Through Time (milliseconds)
V > 1.80	May ride-through or trip
1.70 < V ≤ 1.80	0.2
1.60 < V ≤ 1.70	1.0
1.40 < V ≤ 1.60	3.0
1.20 < V ≤ 1.40	15.0

Based on proposed IBR requirements in NOGRR245

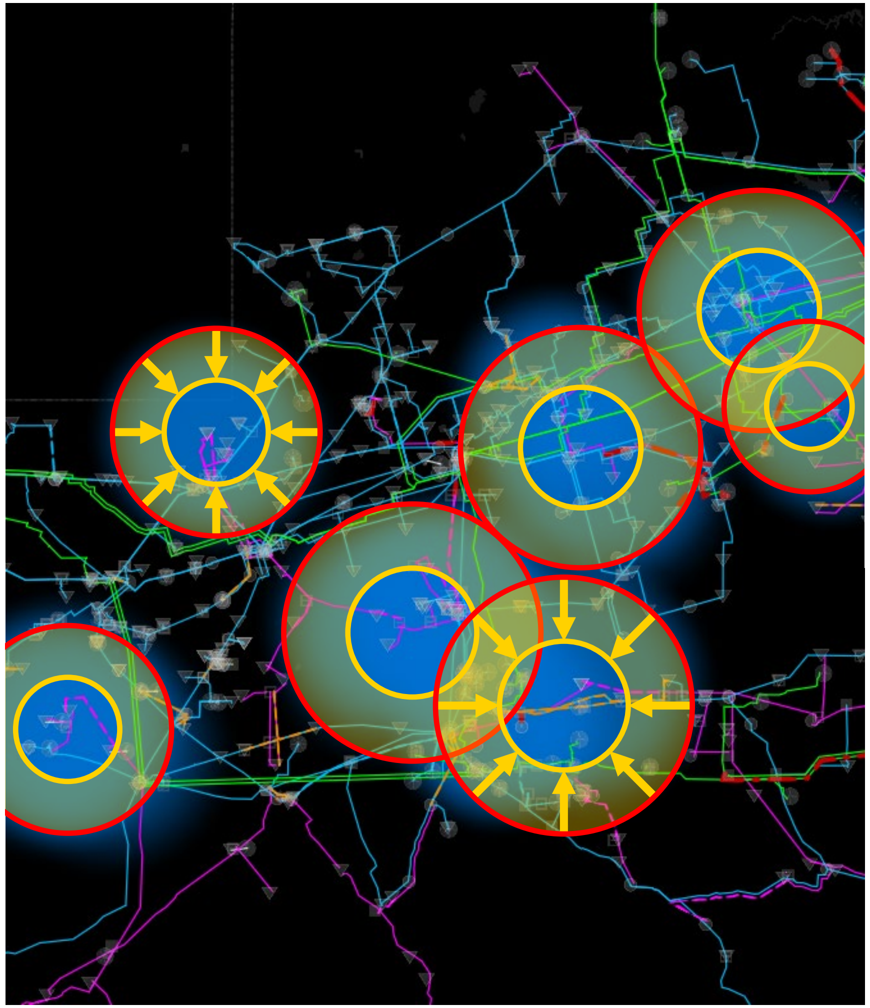
Table proposed in NOGRR256 (now withdrawn)

Approach 2 – Plan the Grid to Limit Load Tripping

- Another approach is to establish new planning criteria to strengthen the grid to reduce the size and area of voltage sag during a fault.

- This would reduce load tripping by reducing the amount of load exposed to the voltage disturbance.

- This approach would require better dynamic models of Large Loads.

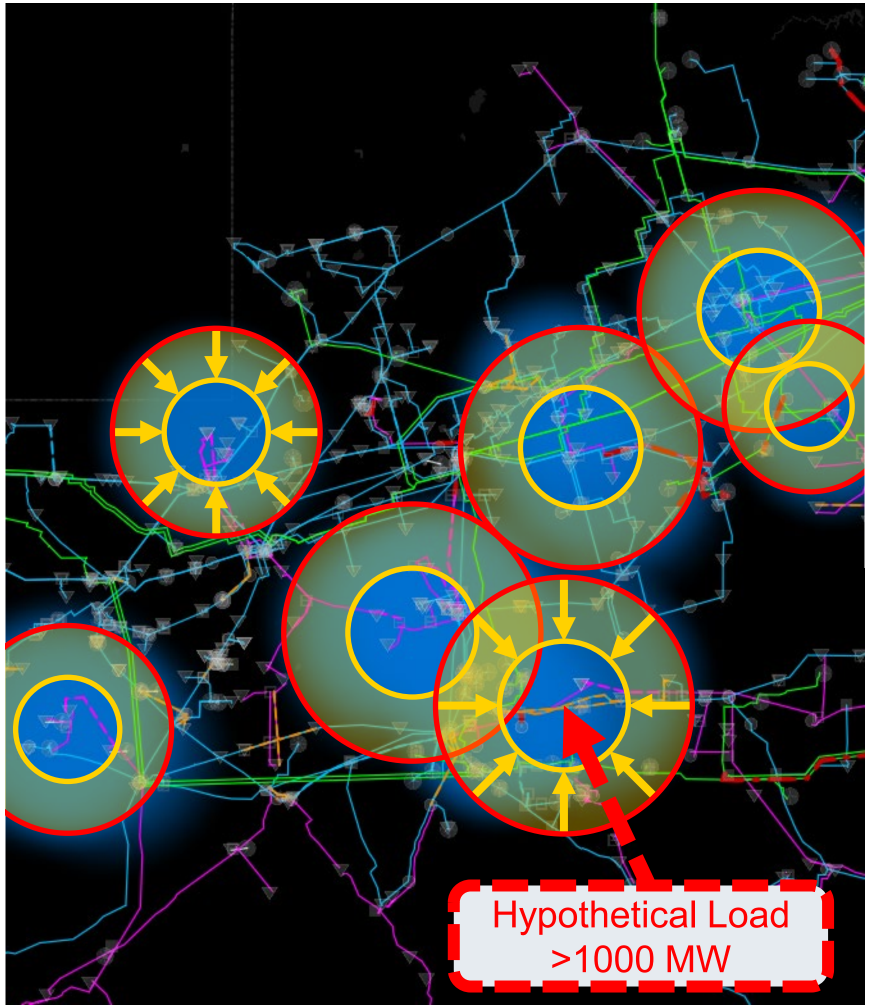


Additional Risk – Large Interconnection Requests

- ERCOT is routinely receiving load interconnection requests greater than 1 GW (some as large as 4 GW).
  - Many of these projects are proposed a single point of connection to the grid without redundant service.

- These concentrations of load at a single site increases the risk of a single contingency tripping a significant amount of load.

- ERCOT is evaluating whether a limit on the amount of load served from a single point is needed to reduce this risk.



Reliability Risks

- Short Interconnection Timelines
- Voltage Ride-Through and Interconnection Size
- Rapid Changes in Consumption
- Forecasting and Predictability
- Alignment of Market Design and Reliability

Reliability Risk – Rapid Variations in Demand

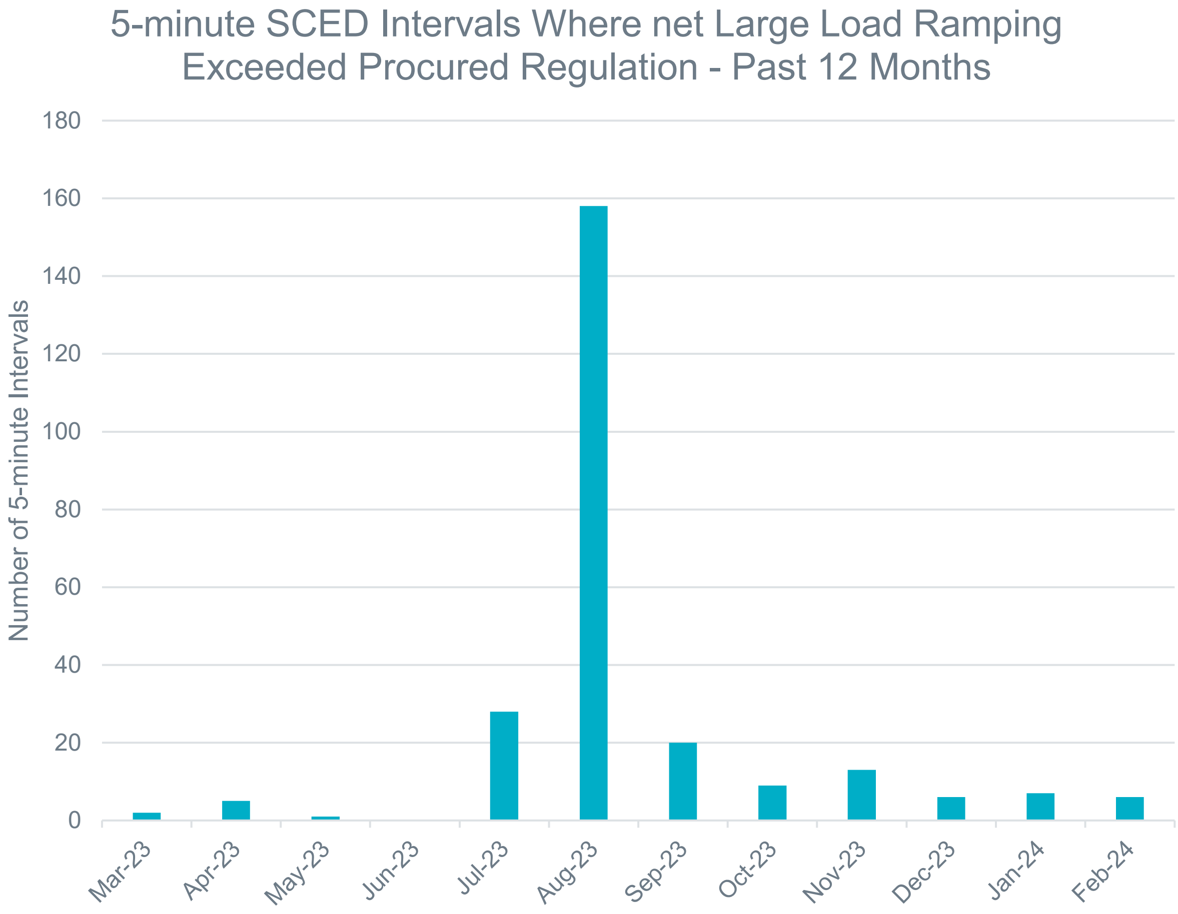
Reliability Risk

A growing number of Large Loads can change their MW consumption rapidly enough to exhaust available Regulation service.

- Large majority of Large Loads today do not participate in ERCOT's Security Constrained Economic Dispatch (SCED)
  - Price responsive Loads may vary consumption at any time without notice or coordination with ERCOT
  - Changes in consumption that occur outside of SCED are also not accounted for when SCED instructs generators how much power to produce

Price Sensitivity and Frequency Control

- In the 12 months ending February 2024,
  - ERCOT experienced **255 five-minute SCED intervals** where the change in Large Load consumption has exceeded the amount of procured Regulation for that interval.
  - ERCOT experienced an **additional 969 intervals** where the change in consumption exceeded at least 50% of procured Regulation.



NOTE: This chart does not indicate Regulation was exhausted in all counted intervals. Multiple factors, including net load and IRR output, determine how much Regulation is used during a 5-minuted SCED interval.

Large Flexible Load Ramping Analysis – Background

Objective – Identify the number of SCED intervals in 2023 where LFL ramping exceeded procured Regulation.

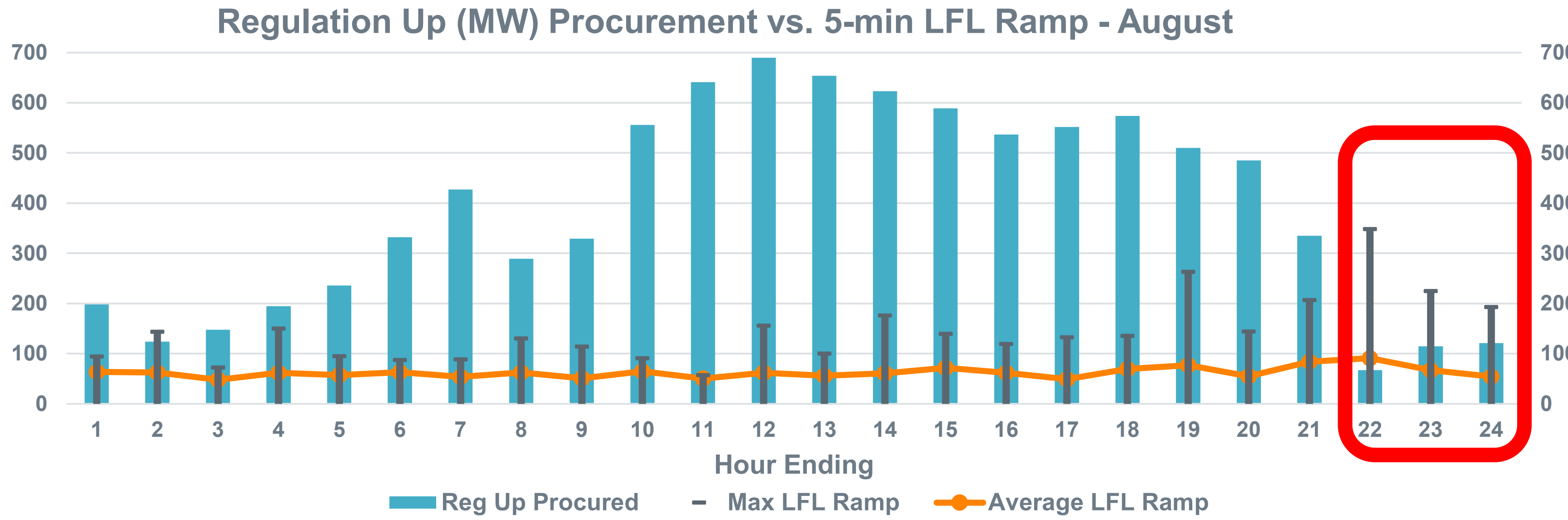
Methodology

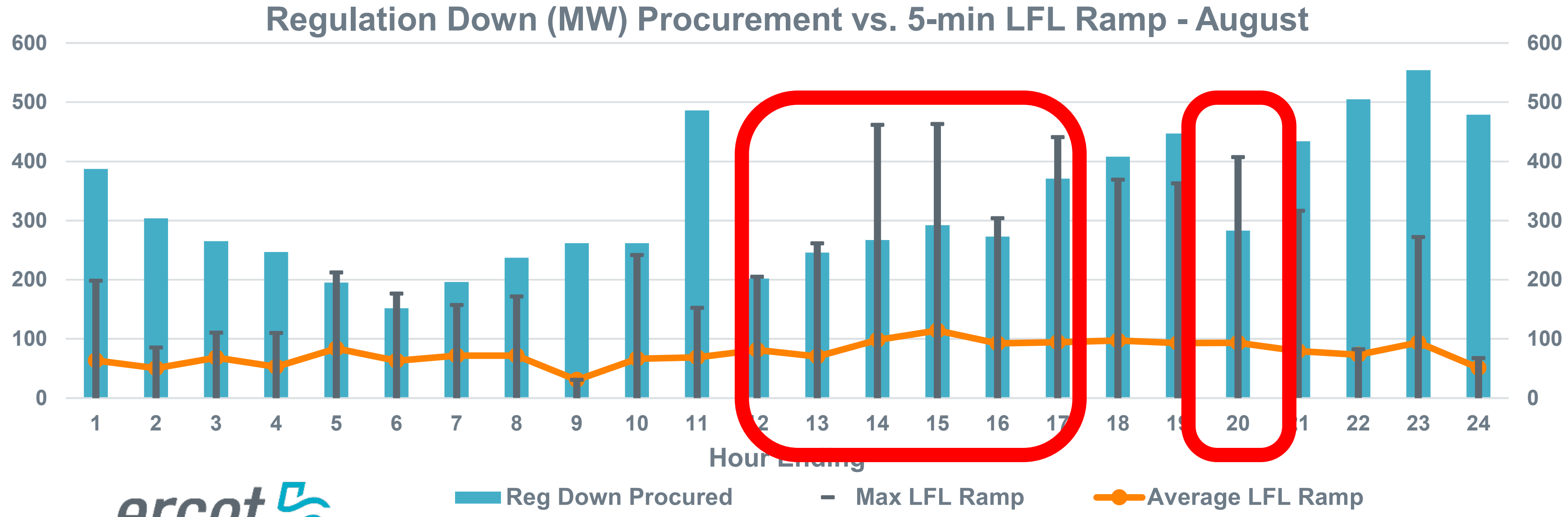
- The amount of total LFL consumption on the ERCOT system was measured every 5 minutes and used to calculate the amount of load ramp (increase or decrease) for each interval.

- All 5-min LFL ramps 20 MW or greater were then compared to the amount of Regulation (in the direction of the load ramp) procured for that interval.

- If the LFL ramp exceeded the amount of procured Regulation for that interval, it was counted.

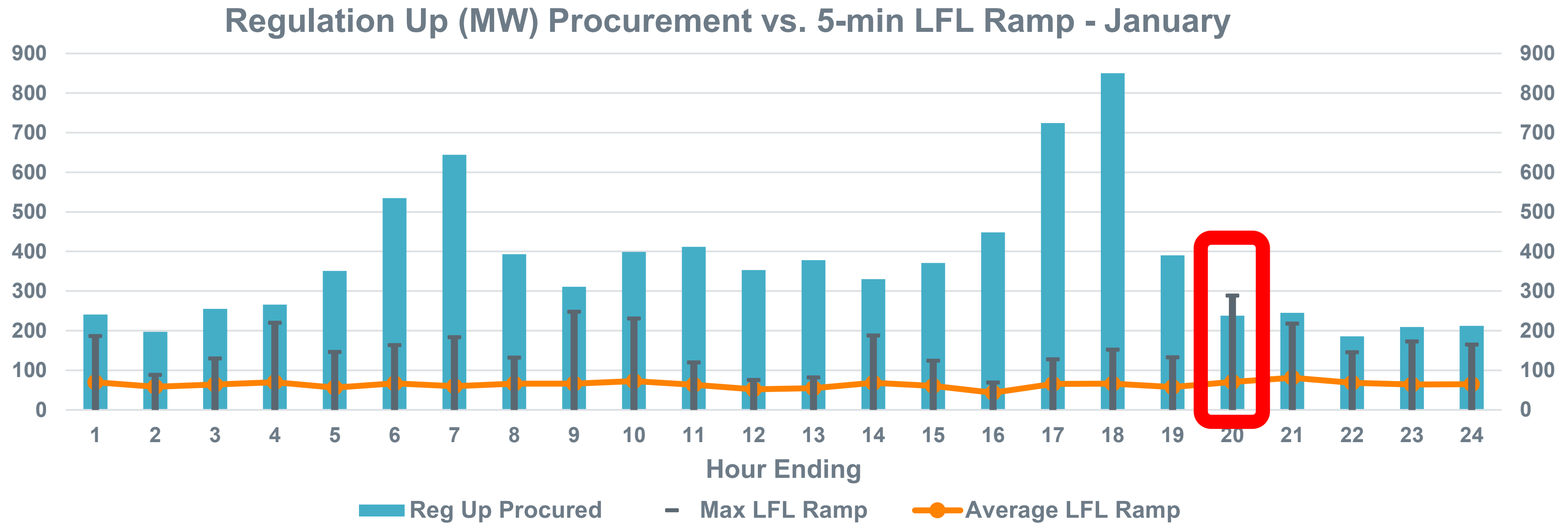
LFL Ramping Analysis – August 2023 (Historical Data)

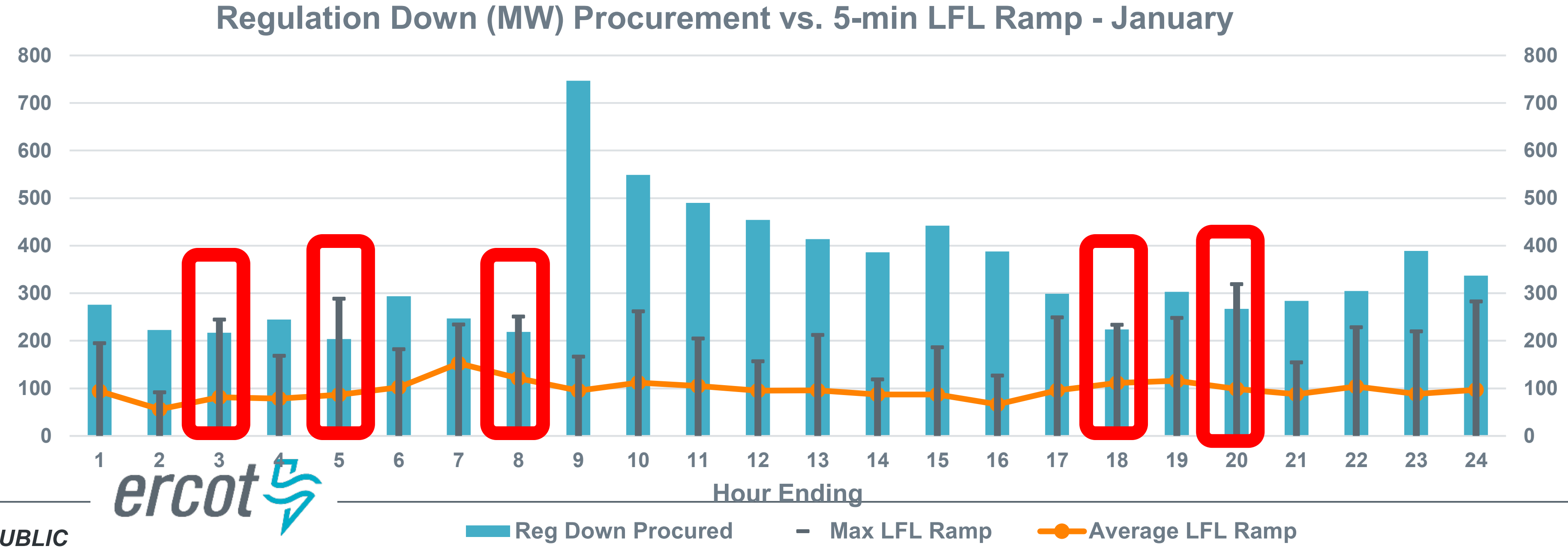




- LFL up-ramp in the late evening already exceeds current regulation-up procurement.
- HE 22 has seen up-ramps 4x greater than currently procured reg-up.
- Early afternoon (HE 12 – 17) has seen down-ramps in excess of available reg-down.

LFL Ramping Analysis – January (Historical Data)





- **Winter months are also seeing considerable LFL ramps.**
- **A total of 6 hours had at least 1 ramp that exceeded the total procured regulation during the month.**
- **Most of these exceedances occurred during down ramps across several hours spread throughout the month.**

PUBLIC

Large Load Ramping – Path Forward

- If all Large Loads with planning studies approved by February 2024 were to connect and exhibit ramping behavior outside of SCED consistent with current loads, 5-minute ramps greater than 400 MW could become routine. Some 5-minute ramps could exceed 2000 MW.

- This would be a risk to the system without ERCOT procuring additional Regulation.

- Procuring more Regulation has downsides
  - Regulation MWs are reserved for that service – procuring more takes MWs out of the pool of dispatchable generation, leaving fewer MWs available during tight conditions
  - Regulation is a paid Ancillary Service – procuring more invites questions of cost causation or increases costs for ratepayers

Reliability Risks

- Short Interconnection Timelines
- Voltage Ride-Through and Interconnection Size
- Rapid Changes in Consumption
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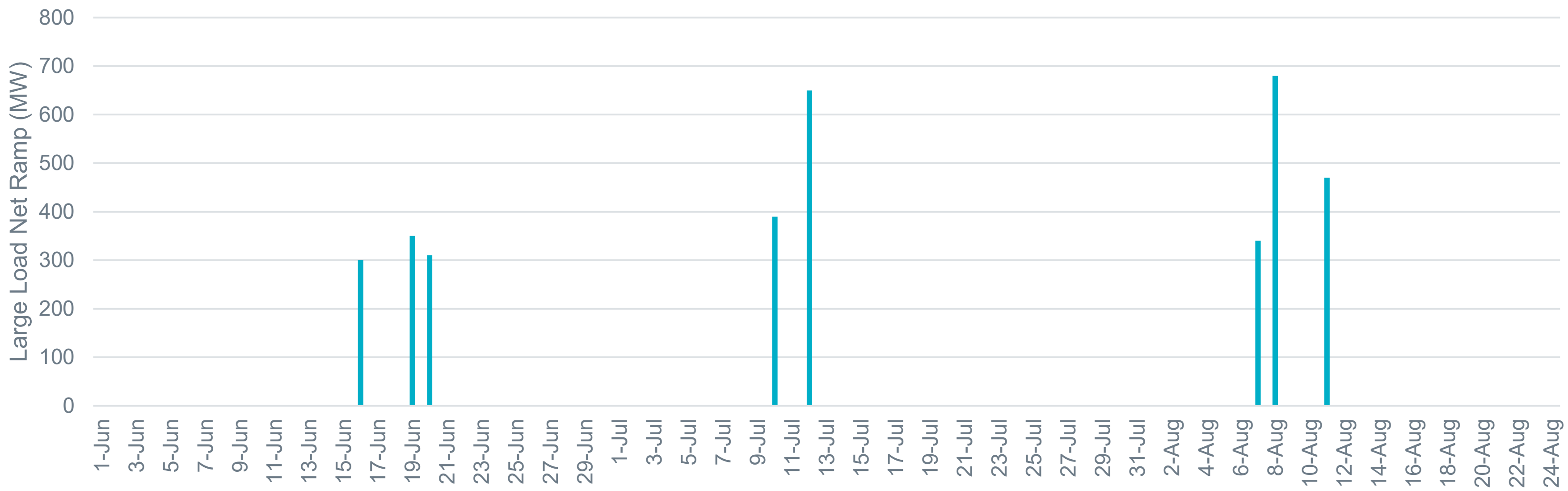
- Alignment of Market Design and Reliability

Summer 2023 – Unexpected Large Load Behavior

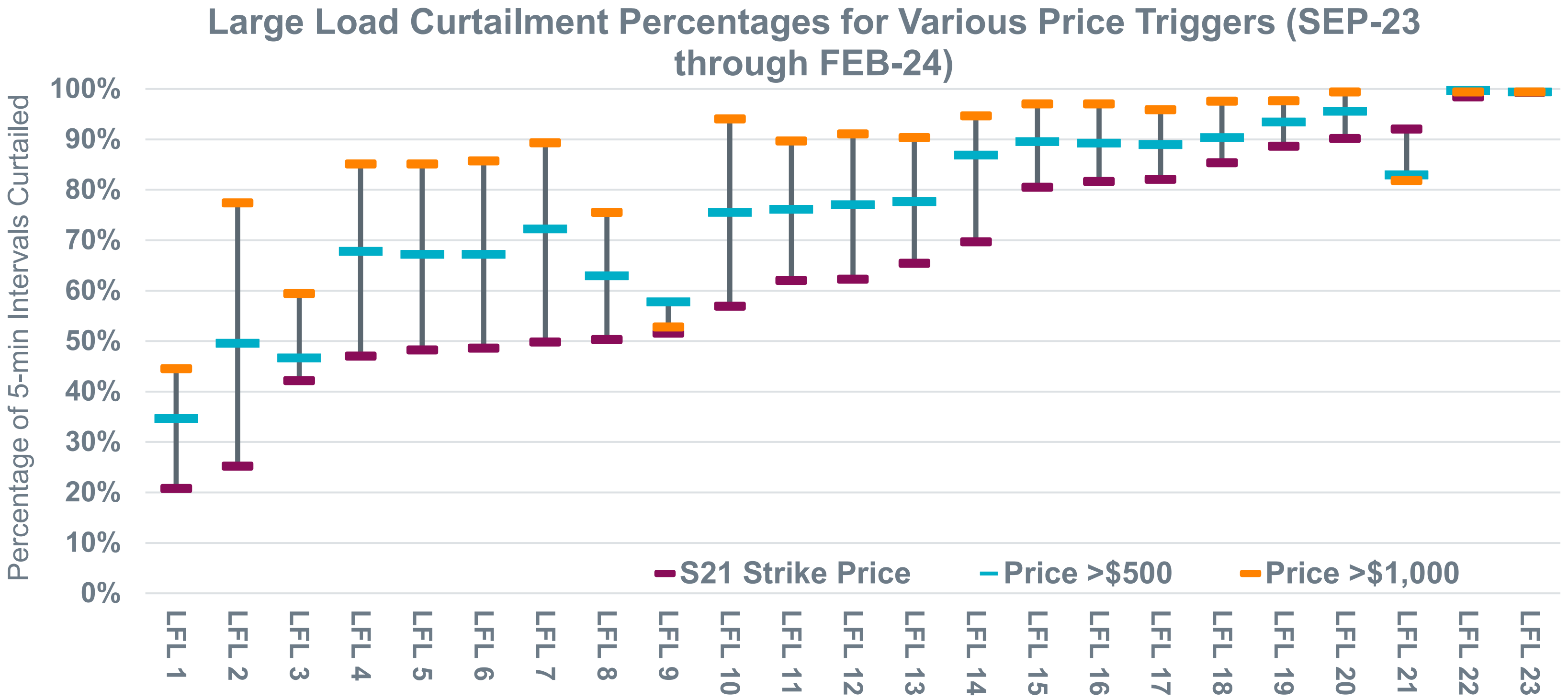
- During Summer 2023, ERCOT experienced 8 operating days where at least 300 MW of Large Load ramped up within 15 minutes when system prices were above $250/MWh and system reserve levels were declining.



- ERCOT also experienced 27 operating days in 2023 where at least 350 MW of Large Load remained online despite prices in excess of $500/MWh.

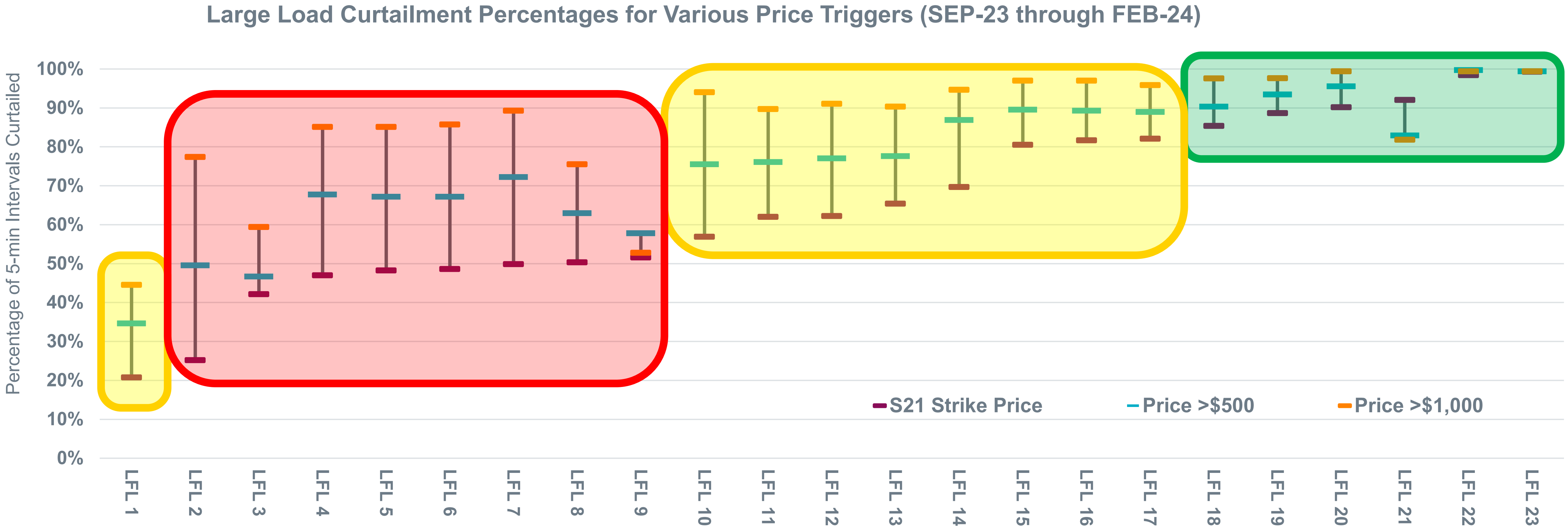
Analysis of Price Responsive Behavior – ERCOT Observations

	% Curtailed S21	% Curtailed $500	% Curtailed $1000
LFL1	20.8%	34.6%	44.5%
LFL2	25.2%	49.6%	77.4%
LFL3	42.1%	46.6%	59.4%
LFL4	47.0%	67.8%	85.1%
LFL5	48.2%	67.2%	85.1%
LFL6	48.6%	67.2%	85.7%
LFL7	49.8%	72.2%	89.3%
LFL8	50.3%	62.9%	75.5%
LFL9	51.6%	57.8%	52.8%
LFL10	56.9%	75.5%	94.0%
LFL11	62.0%	76.1%	89.7%
LFL12	62.2%	77.0%	91.1%
LFL13	65.4%	77.6%	90.3%
LFL14	69.7%	86.9%	94.6%
LFL15	80.5%	89.6%	97.0%
LFL16	81.6%	89.3%	97.0%
LFL17	82.1%	89.0%	95.8%
LFL18	85.4%	90.3%	97.6%
LFL19	88.7%	93.4%	97.6%
LFL20	90.2%	95.5%	99.4%
LFL21	92.0%	82.9%	81.8%
LFL22	98.4%	99.7%	99.4%
LFL23	99.3%	99.4%	99.4%
AVG	65%	76%	86%
AVG (Weighted)	56%	67%	78%



- Chart shows the percentage of intervals where the price was above the indicated trigger AND the load curtailed.
- Price responsiveness varies greatly among large, flexible loads.
- The load weighted averages also show larger LFLs were less price-responsive on average than LFLs as a whole during this period.

Analysis of Price Responsive Behavior – ERCOT Observations



- This chart shows why forecasting flexible behavior is difficult:
  - Highly price sensitive loads can be forecasted since their behavior is generally consistent. (Green)
  - Other loads can be forecasted to some extent as not responsive or only responsive to high prices. (Yellow)
  - Other loads are not easily forecasted without additional information. (Red)

Path Forward – More Loads Participating in SCED

The optimal solution for grid reliability is for more Loads to participate in economic dispatch (SCED) as a Controllable Load Resource (CLR).

Benefits for Loads

- Takes the guesswork out of being responsive to system prices
- Still free to set strike price(s) via bid-to-buy curve
- Eligibility to provide Ancillary Services
- May be able to reliably interconnect more MW*

Benefits for ERCOT

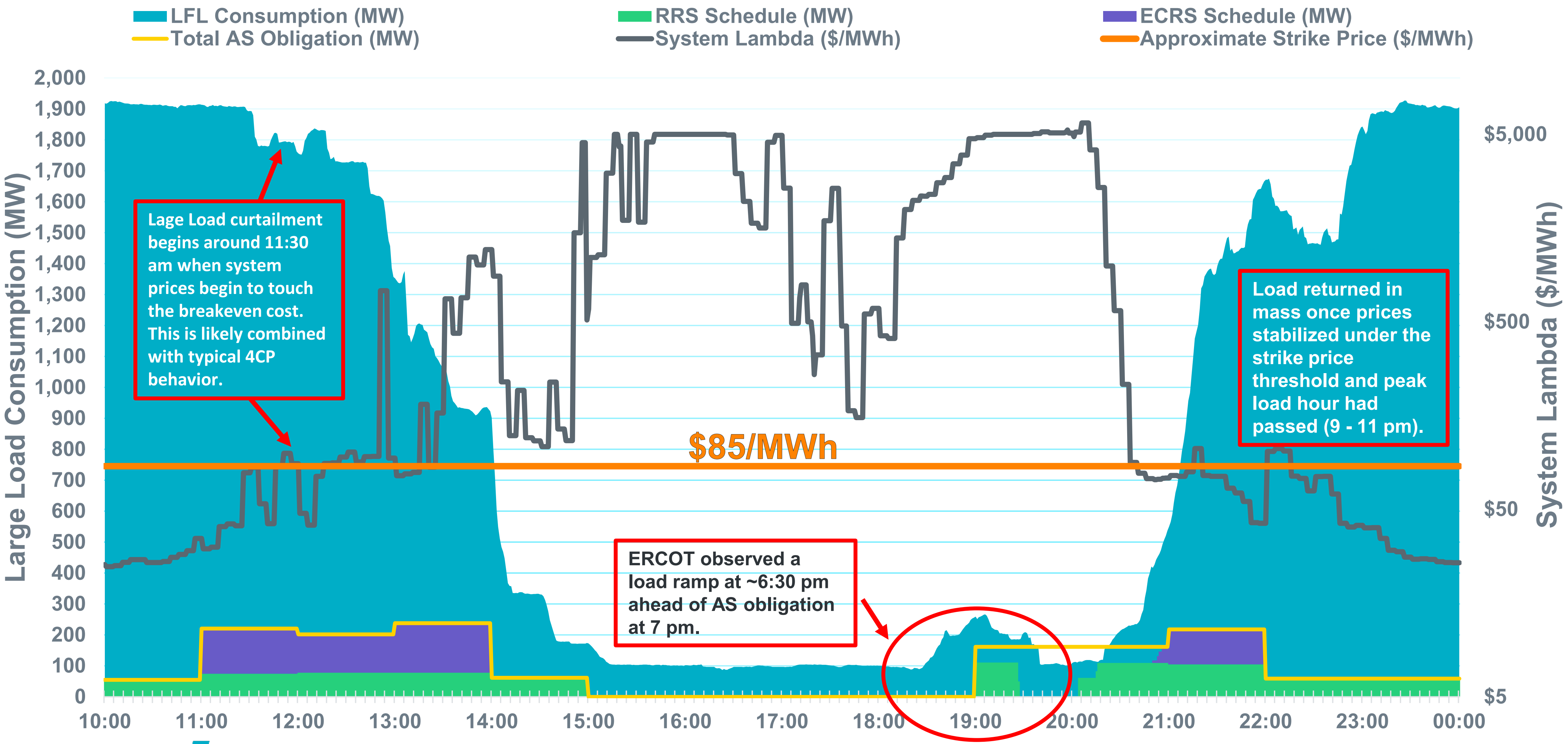
- Load ramping is coordinated with other grid reliability needs
- More data available to aid in forecasting and reliability studies
- More Loads eligible to provide Ancillary Services

* Pending approval of NPRR1188 and future Planning Guide revisions

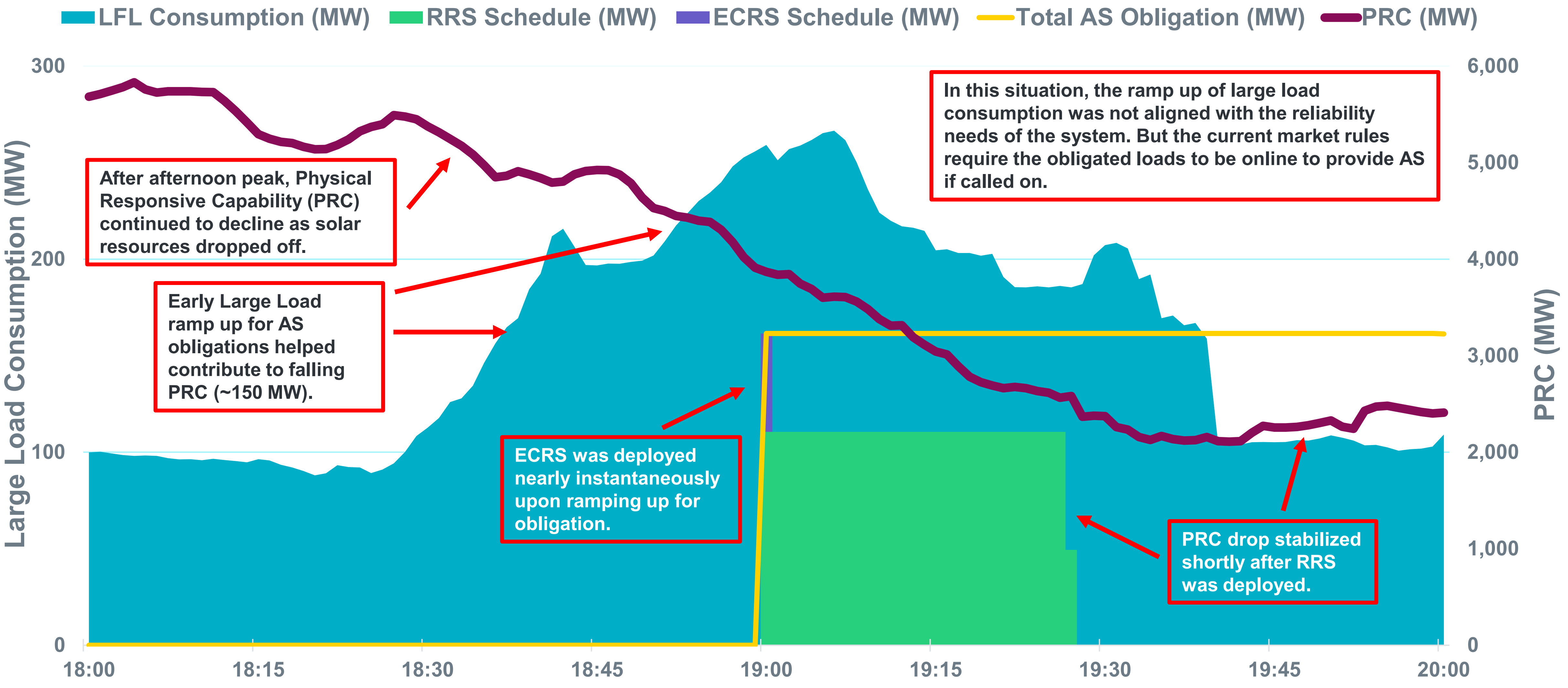
Reliability Risks

- Short Interconnection Timelines
- Voltage Ride-Through and Interconnection Size
- Rapid Changes in Consumption
- Forecasting and Predictability
- Alignment of Market Design and Reliability

Alignment of Market Design and Reliability – 9/6/2023 EEA Event



Alignment of Market Design and Reliability – 9/6/2023 EEA Event



Final Thoughts

- ERCOT, like many grids around the world, is seeing an unprecedented amount of and new types of Large Load interconnecting.

- These Loads raise new risks to grid reliability. Addressing these risks will require changes to traditional thinking and processes. Many questions remain unanswered.

- Large Loads with demand flexibility have the potential to be an important tool for maintaining grid reliability.
  - For this flexibility to enhance rather than detract from grid reliability, it must be coordinated with the other needs of the system.

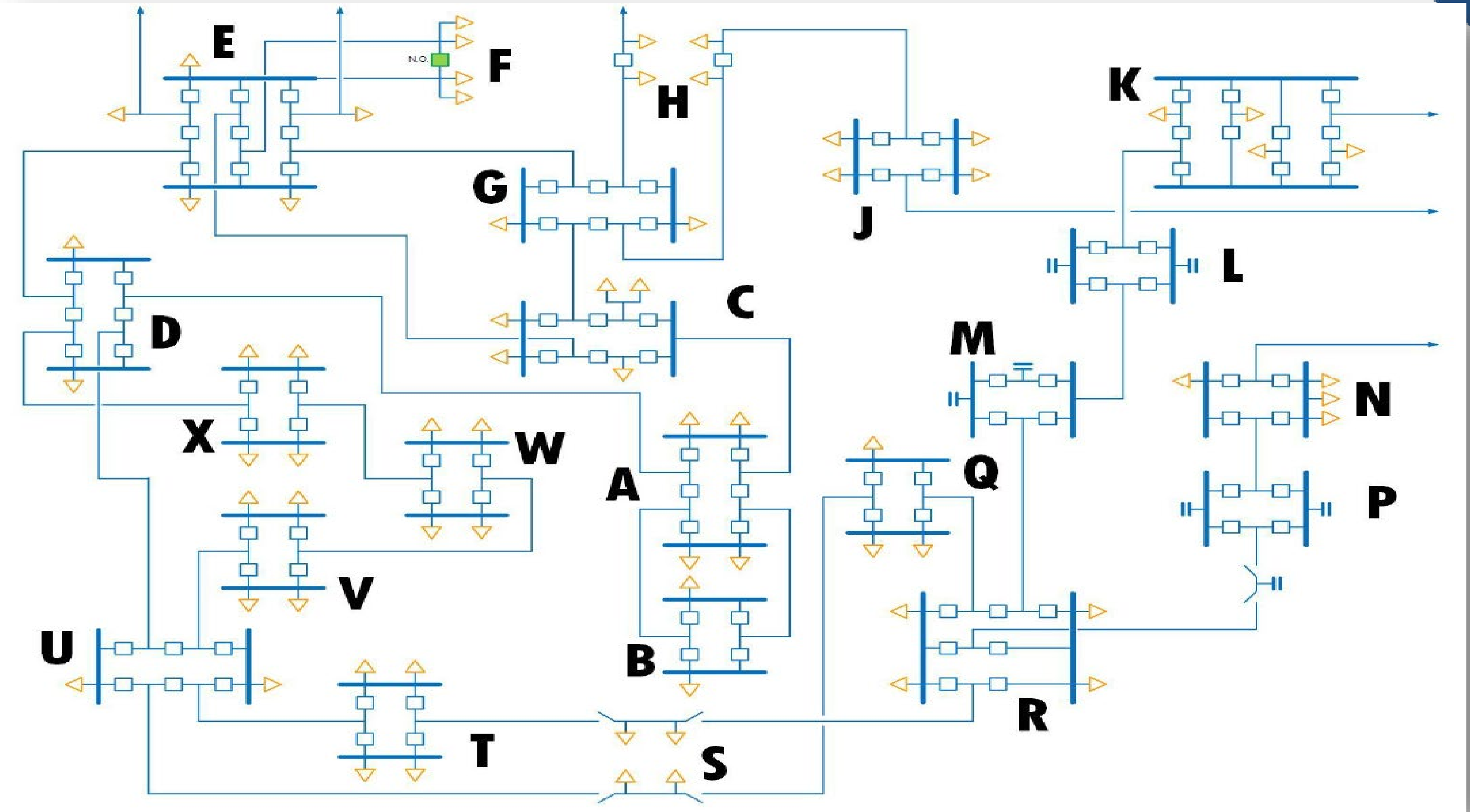
Questions?

Data Center Event

Recent Large Load Loss Event

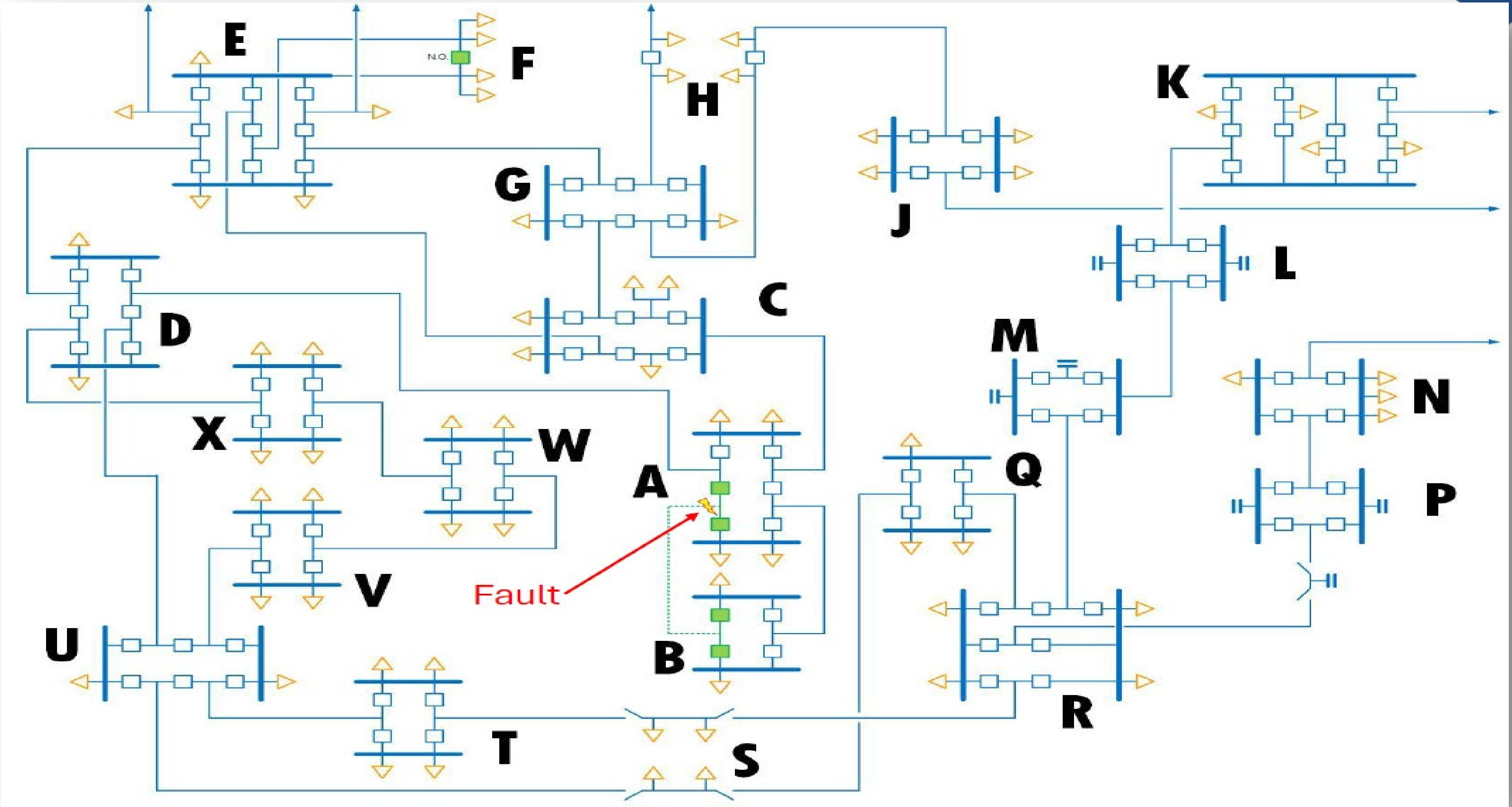
Rich Bauer, Assoc Principle Engineer, Event Analysis - NERC
LLTF Kickoff Meeting
October 8, 2024

Load Loss

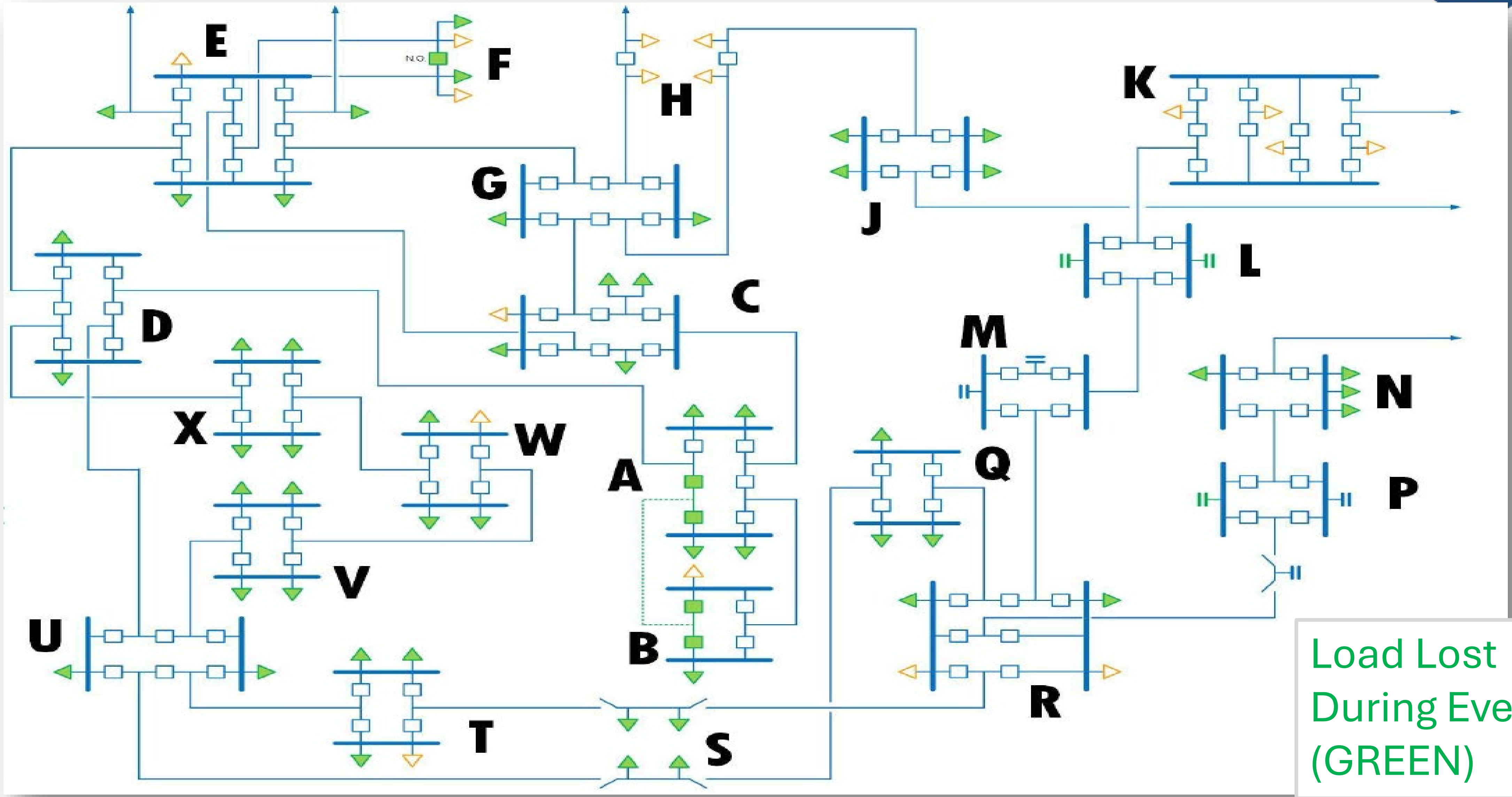


NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Load Loss



Load Loss



Load Lost During Event (GREEN)

Load Loss

Data Center Load Transferred

Station	TX	MVA	Customer
[redacted]	1	10	[redacted]
[redacted]	2	20	[redacted]
[redacted]	3	20	[redacted]
[redacted]	4	20	[redacted]
[redacted]	6	15	[redacted]
[redacted]	1	25	[redacted]
[redacted]	2	10	[redacted]
[redacted]	3	60	[redacted]
[redacted]	5	40	[redacted]
[redacted]	2	2	[redacted]
[redacted]	3	2	[redacted]
[redacted]	1	2	[redacted]
[redacted]	2	2	[redacted]
[redacted]	3	2	[redacted]
[redacted]	4	20	[redacted]
[redacted]	1	60	[redacted]
[redacted]	2	55	[redacted]
[redacted]	3	75	[redacted]
[redacted]	4	45	[redacted]
[redacted]	3	10	[redacted]
[redacted]	4	2	[redacted]
[redacted]	5	5	[redacted]
[redacted]	1	5	[redacted]
[redacted]	3	13	[redacted]
[redacted]	4	2	[redacted]
[redacted]	3	8	[redacted]
[redacted]	1	2	[redacted]
[redacted]	2	5	[redacted]
[redacted]	3	3	[redacted]
[redacted]	4	20	[redacted]

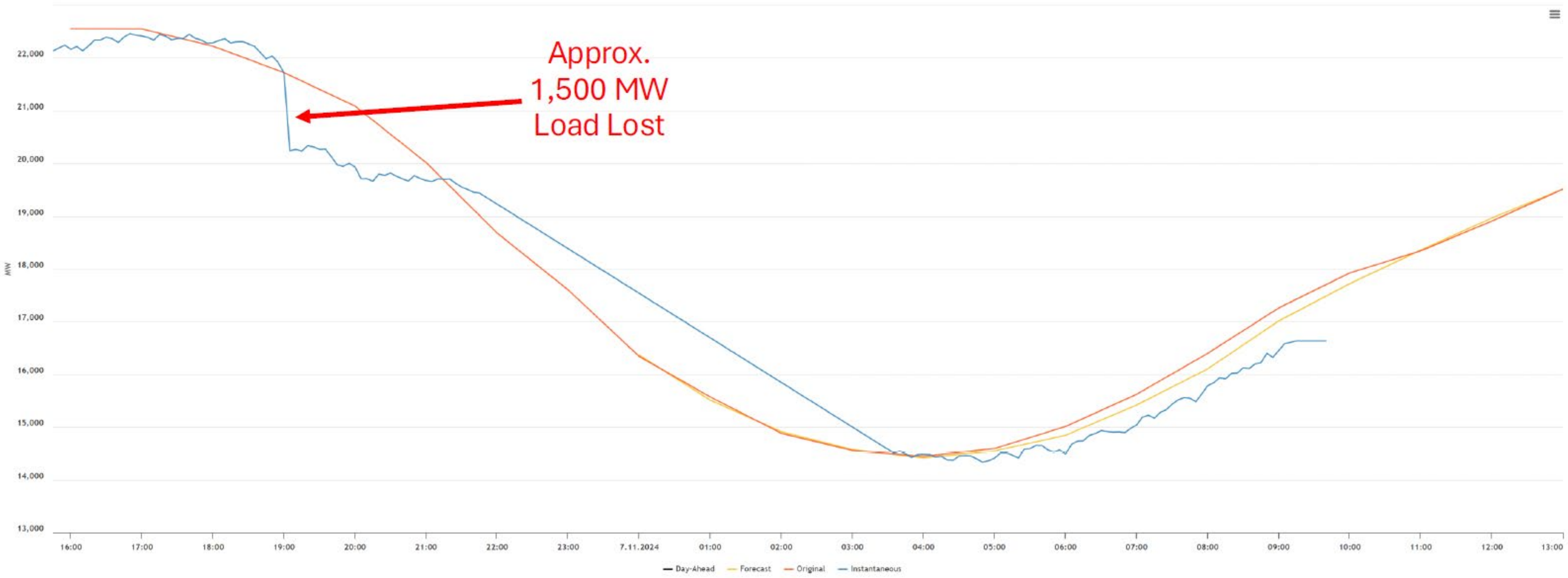
Station	TX	MVA	Customer
[redacted]	4	10	[redacted]
[redacted]	2	22	[redacted]
[redacted]	3	20	[redacted]
[redacted]	4	10	[redacted]
[redacted]	2	2	[redacted]
[redacted]	4	10	[redacted]
[redacted]	1	30	[redacted]
[redacted]	2	40	[redacted]
[redacted]	3	40	[redacted]
[redacted]	4	30	[redacted]
[redacted]	1	72	[redacted]
[redacted]	2	95	[redacted]
[redacted]	1	72	[redacted]
[redacted]	2	55	[redacted]
[redacted]	3	32	[redacted]
[redacted]	6	27	[redacted]
[redacted]	2	15	[redacted]
[redacted]	3	10	[redacted]
[redacted]	3	35	[redacted]
[redacted]	4	35	[redacted]
[redacted]	1	5	[redacted]
[redacted]	2	10	[redacted]
[redacted]	3	15	[redacted]
[redacted]	4	15	[redacted]

Station	DP	MVA	Customer
[redacted]	1	50	[redacted]
[redacted]	2	10	[redacted]
[redacted]	1	45	[redacted]
[redacted]	1	82	[redacted]
[redacted]	1	55	[redacted]
[redacted]	2	42	[redacted]

DEV SUBTOTAL = 1,267
COOP SUBTOTAL = 284
TOTAL LOAD = 1,551

The 1551 MWs are dispersed between 25-30 substations and are roughly 60 individual data centers. They range from 2 MVA to 85 MVA..

Load Loss


Approx.
1,500 MW
Load Lost
22,000
21,000
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
MW
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
7.11.2024
01:00
02:00
03:00
04:00
05:00
06:00
07:00
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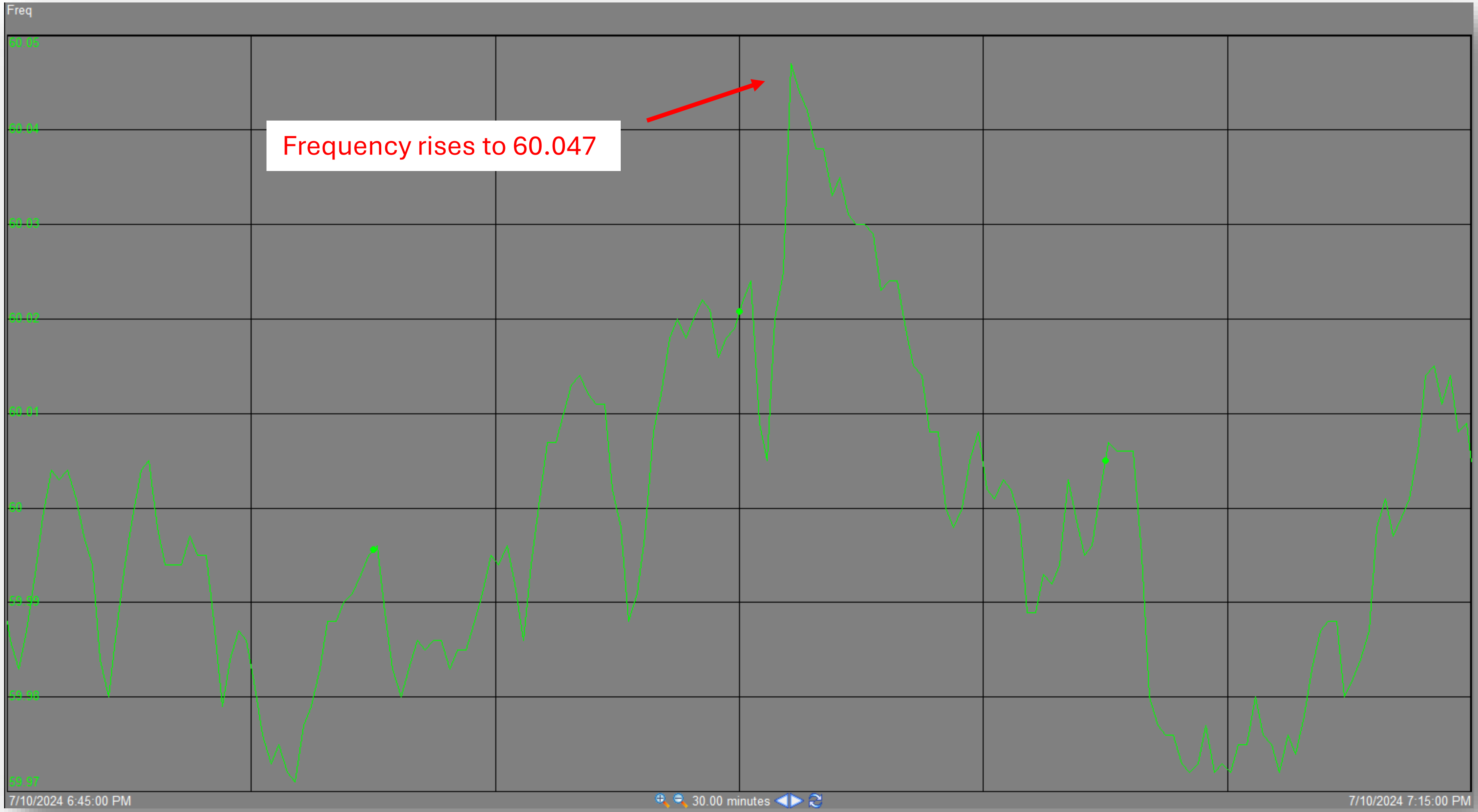
09:00
10:00
11:00
12:00
13:00
Day-Ahead
Forecast
Original
Instantaneous

Load Loss Effects



Load Loss Effects

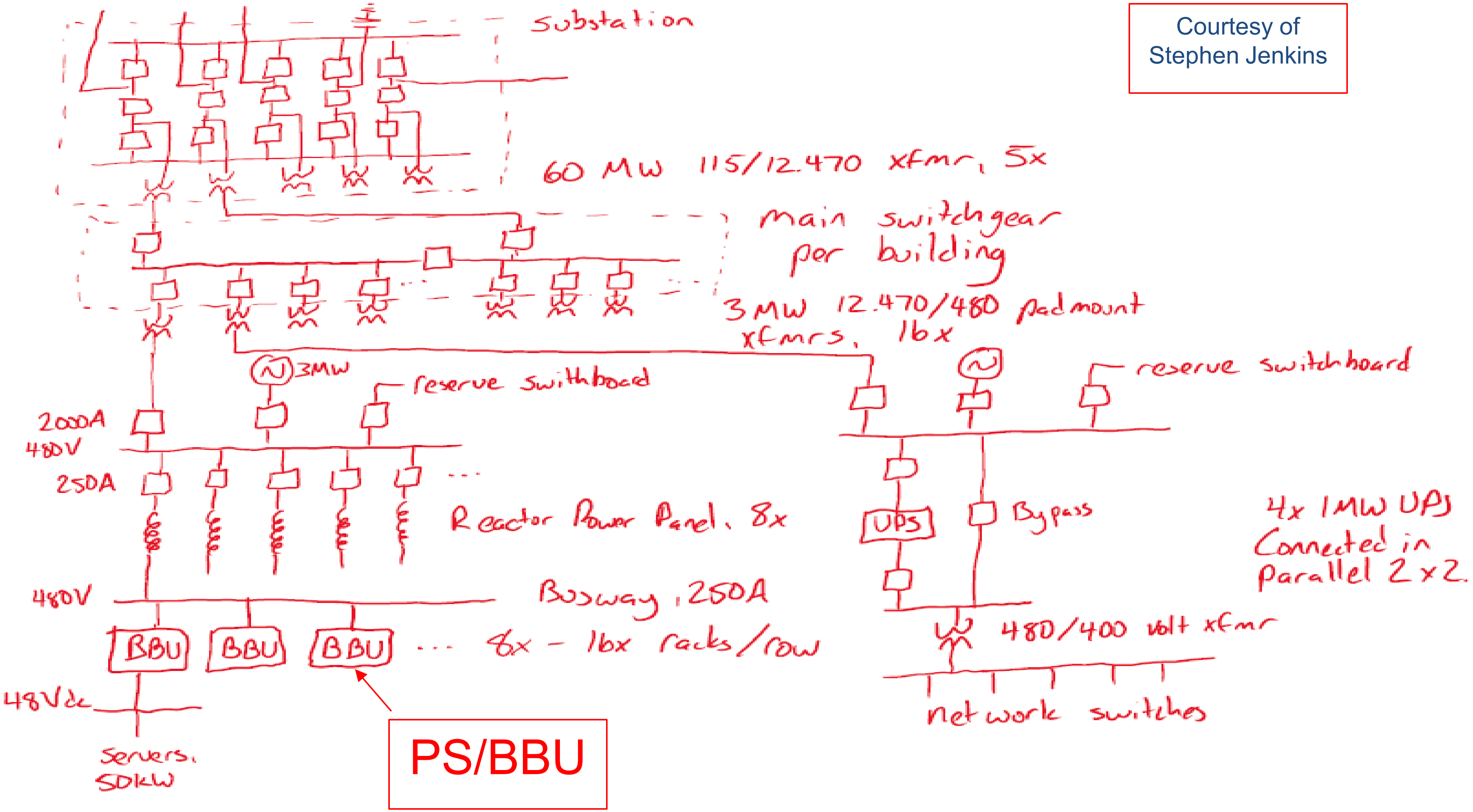
- High Voltage
- Less than 1.1 per unit
- Operators removed local area 230 kV capacitor banks to reduce voltage

Analysis

200 MW Datacenter Conceptual Drawing

Thursday, August 8, 2024 8:40 AM

Courtesy of Stephen Jenkins



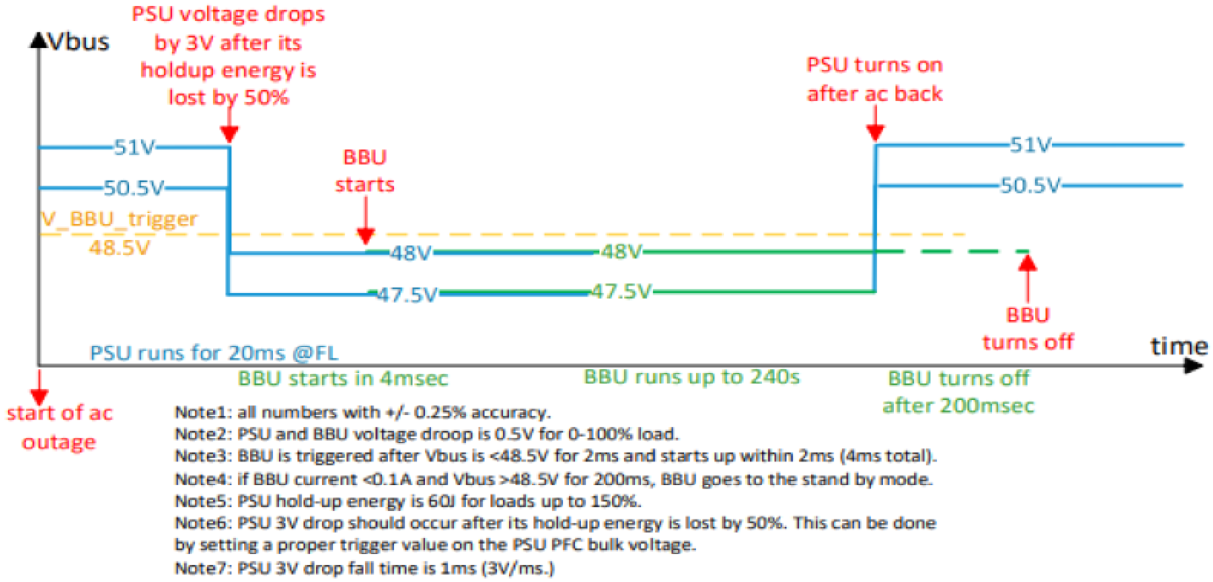
BBU After Loss of AC

Courtesy of Stephen Jenkins

4.5. Transition between Power Shelf and BBU Shelf

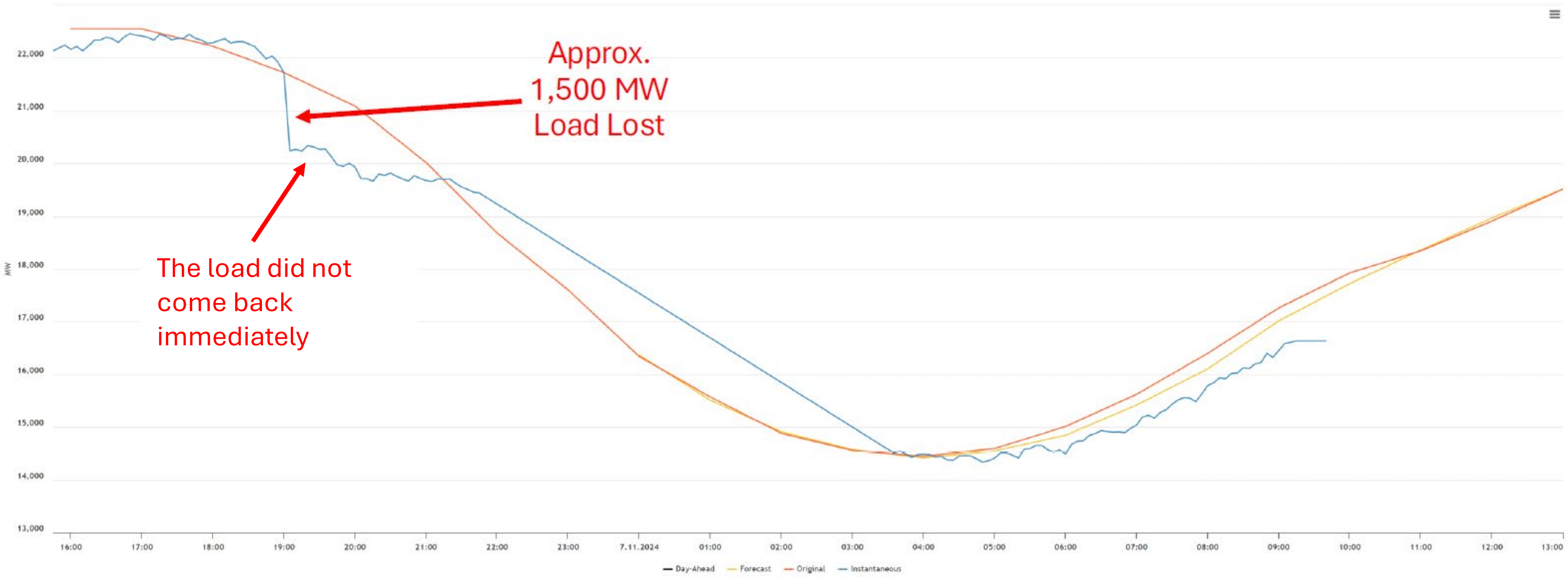
BBU shall constantly monitor busbar voltage. When the busbar voltage declines to the BBU activation level 48.5V for 2ms+/-0.1ms (TBD), the BBU shelf output voltage shall ramp up to provide full power to the busbar within <2ms. During the transition, the busbar voltage shall never drop below 46V.
When the BBU shelf detects that the busbar voltage is above 48.5V for >200ms (TBD), the BBU shelf exits discharge mode.

PSU/BBU Power Transition Diagram
Figure 2



- BBU outage is detected by drop in DC bus voltage below 48.5V for 2ms.
- This may not happen in a “brown-out” as the active rectifier will simply increase duty cycle, draw more current to regulate the DC voltage.
- Restores 100% of load 200ms after DC bus voltage recovers.
- Adds additional charging load of 800 W upon restoration from a longer outage.

Load Loss


Approx.
1,500 MW
Load Lost
The load did not
come back
immediately
MW
22,000
21,000
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
16:00
17:00
18:00
19:00
20:00
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7.11.2024
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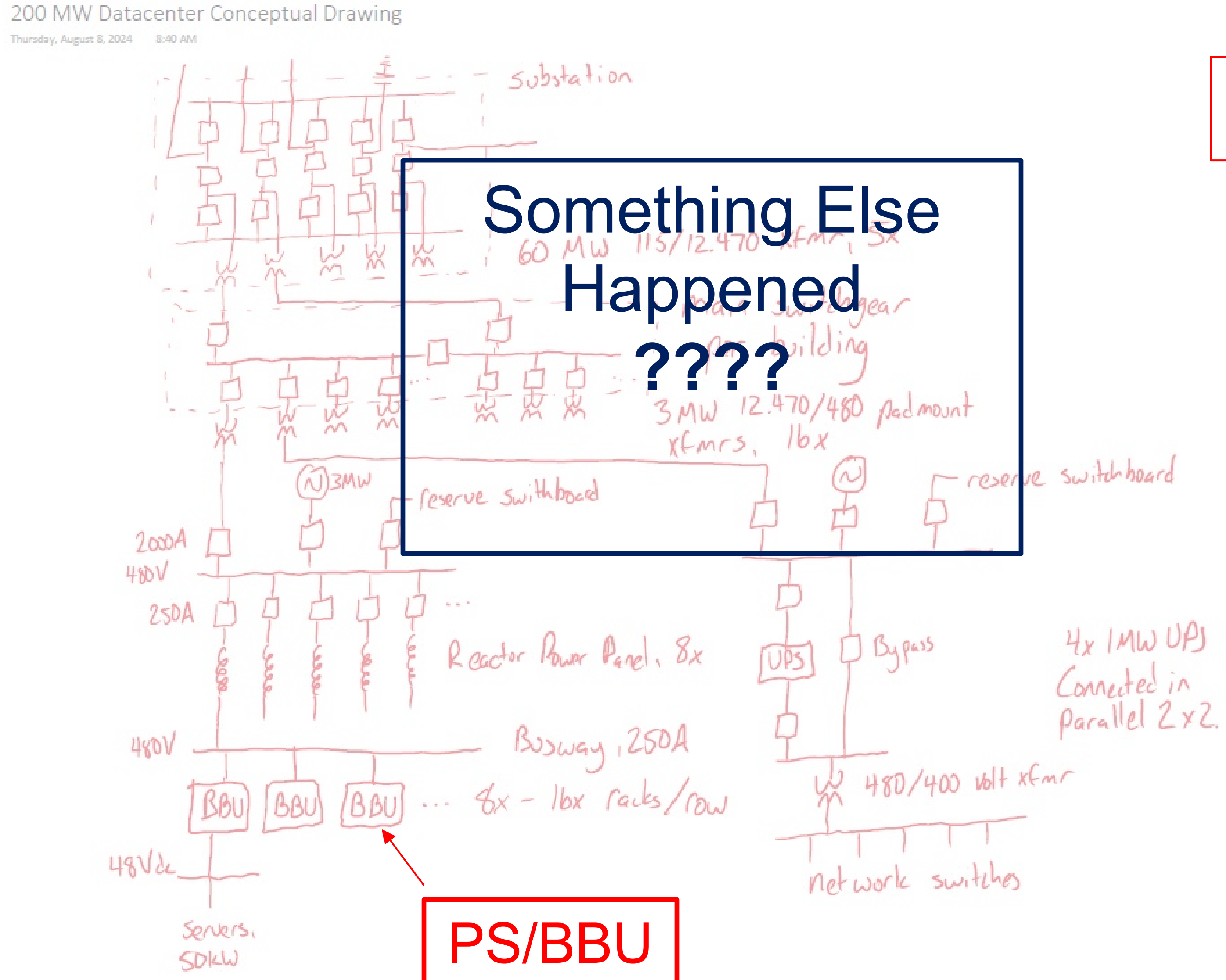
12:00
13:00
Day-Ahead
Forecast
Original
Instantaneous

Courtesy of Stephen Jenkins



Something Else Happened ????

PS/BBU

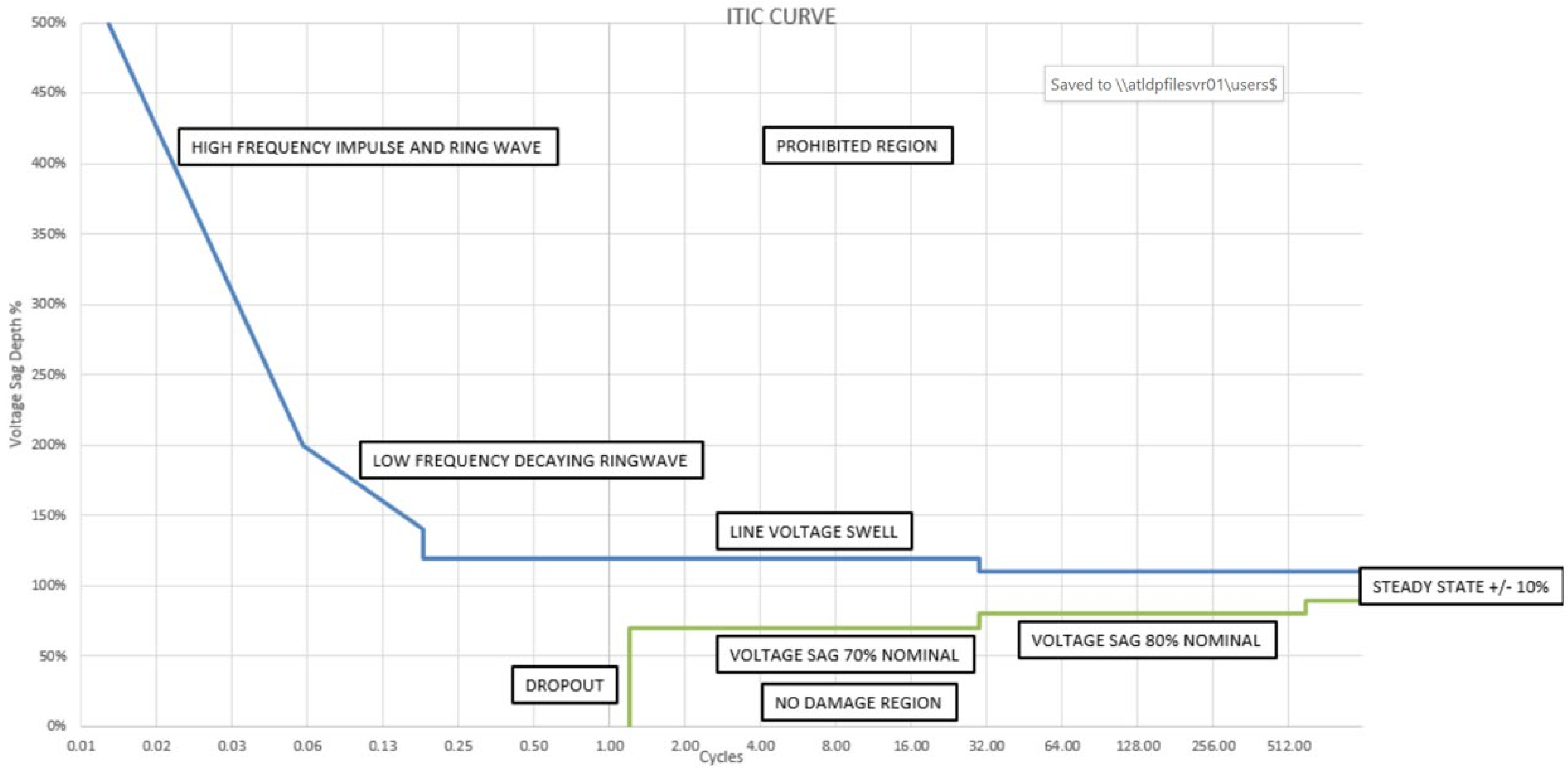
Next Steps

- Short Term
  - Gathering PMU data
  - Engaging Data Centers to determine specifically what happened at their sites
  - Publish a Reliability "Vignette"
  - Engaging Advanced System and Analytics Modeling (ASAM)
    - Studies to assess/identify risk
- Longer Term
  - Present "Vignette" at RSTC meeting
  - Inform and work with Large Loads Task Force (LLTF)
    - Whitepapers – Guidelines

BTW…

- The Texas Interconnection has experienced some large load loss events
  - Large Flexible Load Task Force (LFLTF)
- WECC has a Large Load Risk Assessment project
  - Industry Advisory Group

Update...



ITIC CURVE

Questions

PROJECT SPONSORED BY

CLEAN GRID INITIATIVE

Grid Strategies

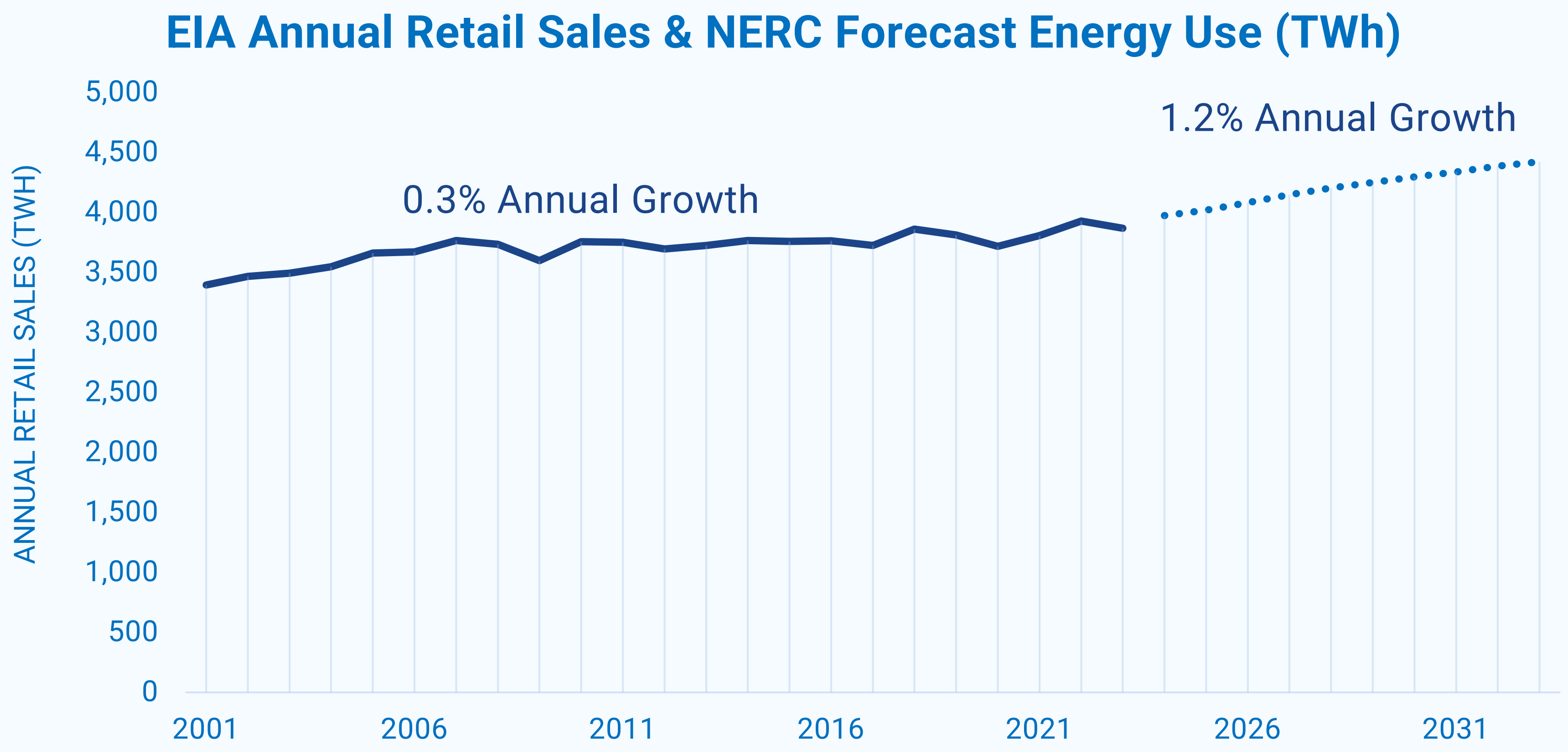
The Era of Flat Power Demand is Over

2024 "Early Release" for NERC Large Loads Task Force

John D. Wilson and Zach Zimmerman

October 2024

The Era of Flat Power Demand is Over



SOURCE | EIA, *Electricity Data Browser and Electricity Monthly Update* (February 2024); NERC, *2023 Electric Supply & Demand* (December 2023).

GridStrategies

$630 Billion in Near-Term Investment in "Large Loads" is Increasing Expectations for Load Growth

THE STORY IS SIMPLE …

Over the past two years, grid planners have tripled the 5-year load growth forecast.

- Energy demand forecast: **Up from 2.8% to 8.1% growth**
- Grid planners forecast peak demand **growth of 66 GW through 2029**
- Many of the factors that suggested last years' forecast was an **underestimate** may have been addressed

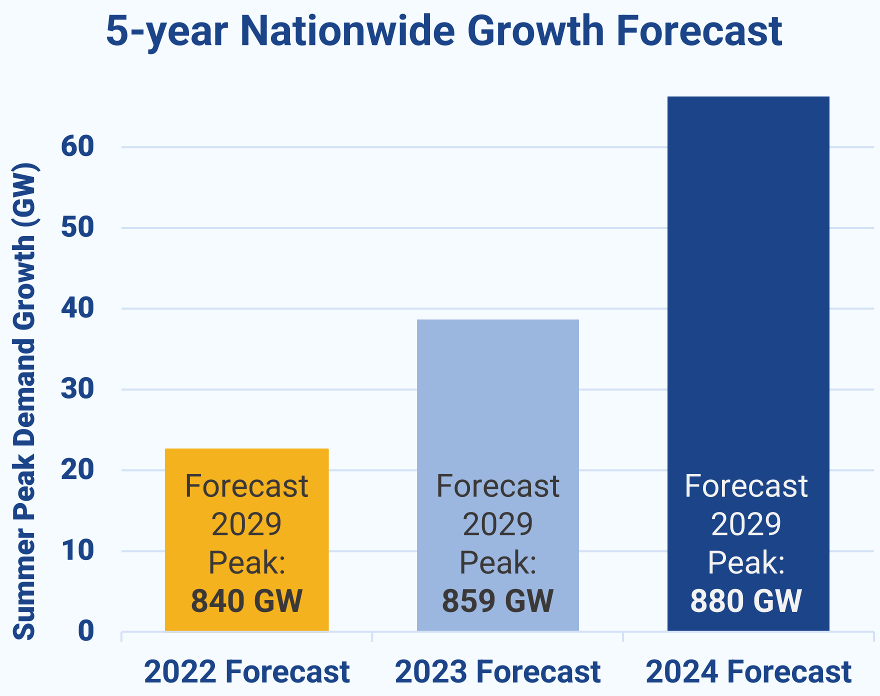
Our 2023 report found that the main drivers are investment in new manufacturing, industrial, and data center facilities.

- **$481 billion in commitments** since 2021 - over 200 manufacturing facilities announced in 2023
- Data center growth expectations vary widely, from **15 to 60 GW by 2030**

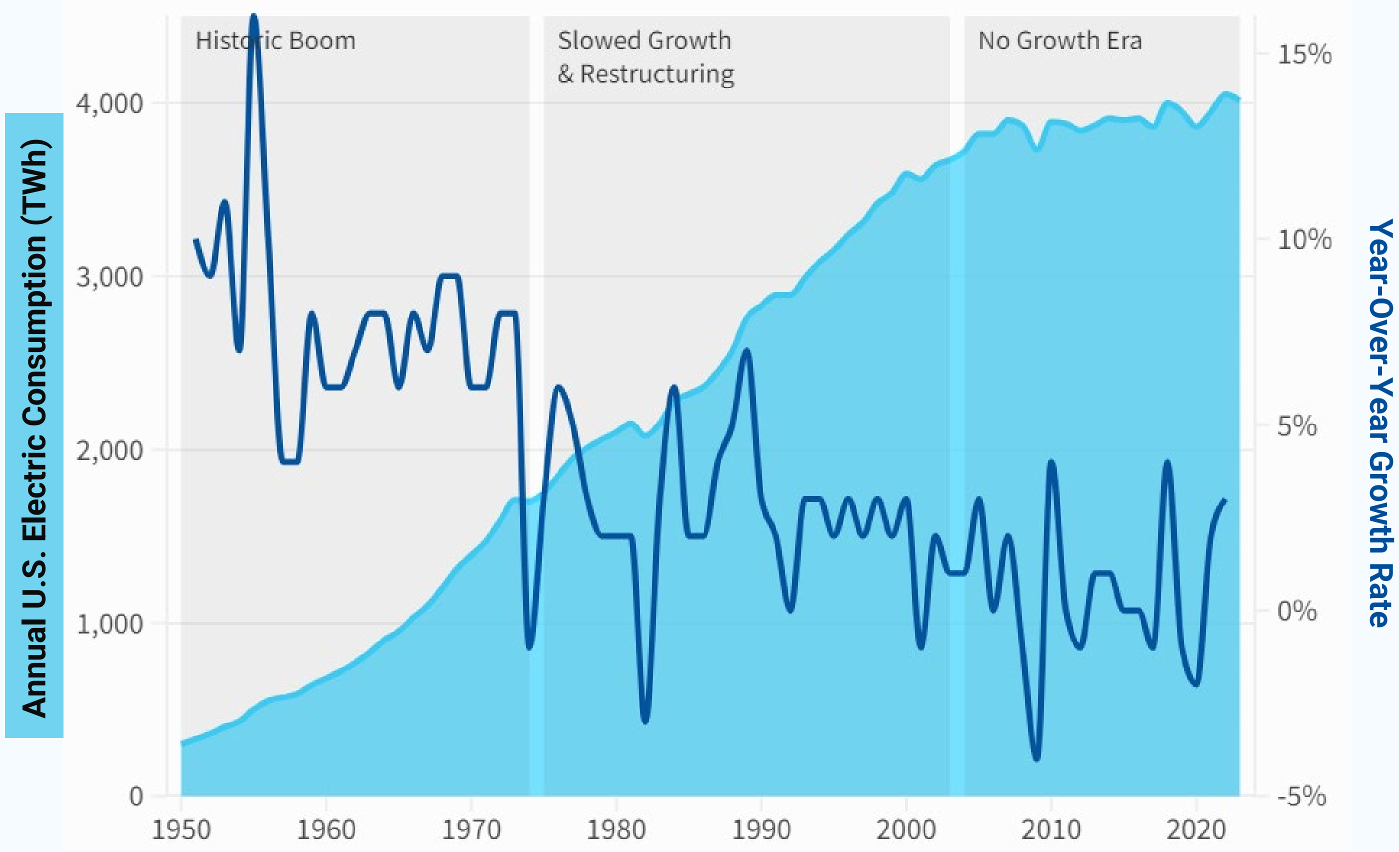
The U.S. electric grid is not prepared for significant load growth.

- Annual additions of only 645 miles of new transmission lines in the second half of the 2010s

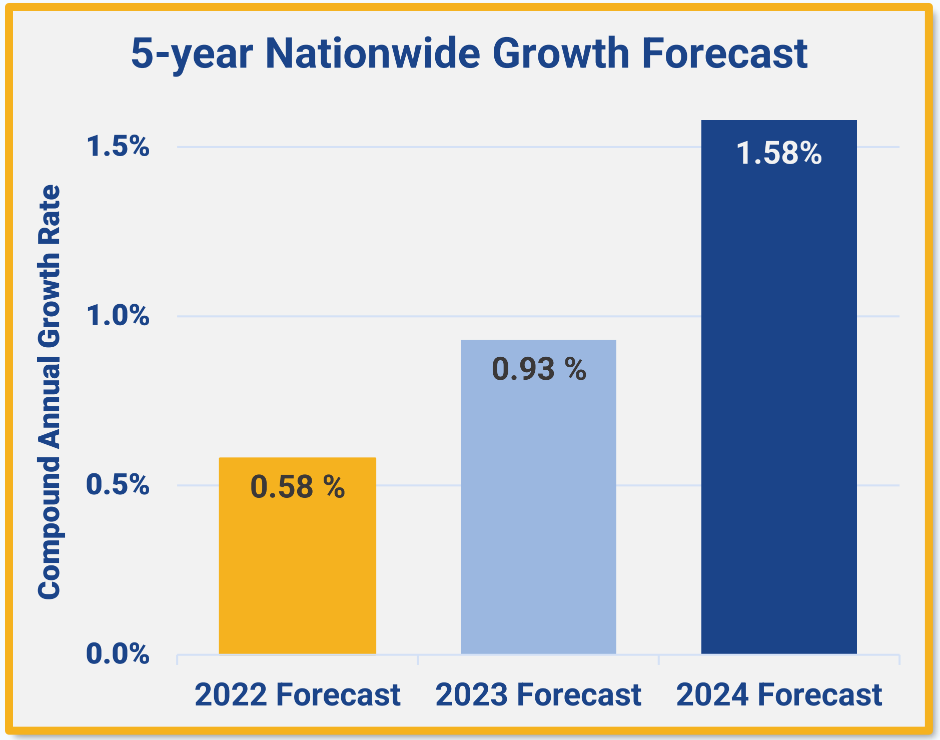
AND THE FORECASTS ARE SHOCKING …



Power Demand Eras



SOURCE | CSIS, Strategic Perspectives on U.S. Electric Demand Growth (2024).



Grid Strategies

Planning Areas with Sharpest Increase in 2024 Load Forecast

Not all regions of the country are reporting a sharp increase in the 2024 load forecast. **Ten planning areas report most of the increase:** 39 GW in higher summer peak demand forecast for 2029 compared to the forecast two years ago.

Key Changes from our 2023 Report:

- MISO and PacifiCorp are now on the top-ten list
- Puget Sound Energy and CAISO dropped off the top-ten list and now show **negative growth** over the next five years

Our 2024 Report …

Reminder that this is an "early release" of data that we will publish in our report, and we will evaluate these and other trends in the final report.

Planning areas with greatest increase in summer 2029 peak demand

Planning Area	2022 Forecast (GW)	2023 Forecast (GW)	2024 Forecast (GW)	Increase (GW)	Percent Increase
PJM	153.3	156.9	165.7	**12.3**	8.1%
Georgia Power	16.3	17.3	22.4	**6.2**	38.0%
MISO	132.4	133.0	138.4	**6.1**	4.6%
SPP	56.6	59.5	62.5	**5.9**	10.4%
ERCOT	84.4	89.6	88.1	**3.7**	4.4%
Duke Energy (North & South Carolina)	33.9	36.2	36.6	**2.7**	7.8%
Arizona Public Service	8.7	9.8	9.9	**1.2**	13.6%
PacifiCorp	14.1	14.2	15.2	**1.1**	7.7%
NYISO	31.5	32.3	32.3	**0.9**	2.8%
Tennessee Valley Authority	31.8	32.4	32.5	**0.7**	15.7%
All other planning areas	277.5	277.6	276.1	**-1.4**	-0.5%
Total	**840.5**	**858.9**	**879.8**	**39.3**	**4.7%**

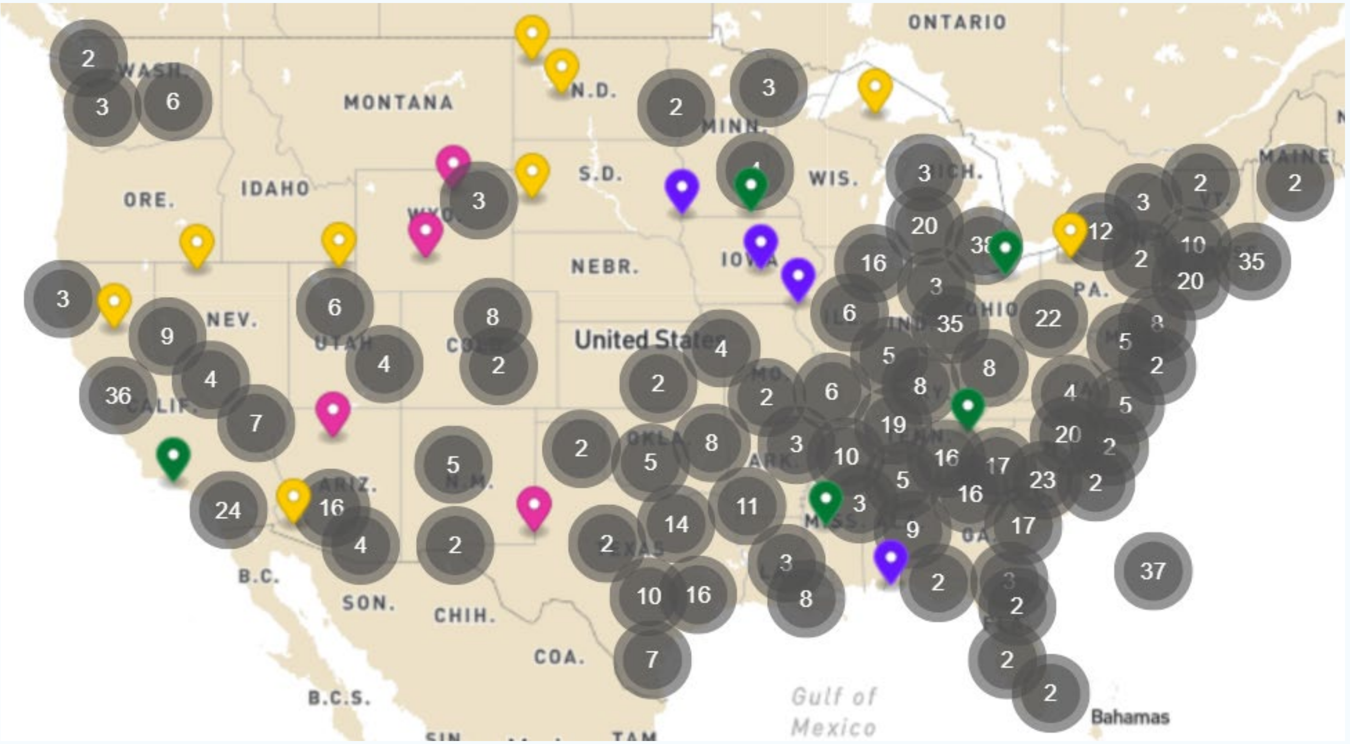
Three Regions Hosting Most New Industrial Load

Investments are concentrated in:

- **Southeast**, especially Georgia, the Carolinas, Tennessee and Kentucky
- **Midwest**, especially Michigan, Indiana and Ohio
- **Southwest**, especially Arizona and Nevada

Near-term load growth associated with these facilities is now appearing in all of these regions.

Announced Manufacturing Facilities since August 2022



SOURCE | U.S. Department of Energy, Building America's Clean Energy Future (accessed June 5, 2024).

DUKE ENERGY
NORTH AND SOUTH CAROLINA

"Mega-Projects"

The Duke Energy planning area 2028 forecast increased from 33.8 GW to 35.8 GW in the past year, a 5.9% increase.

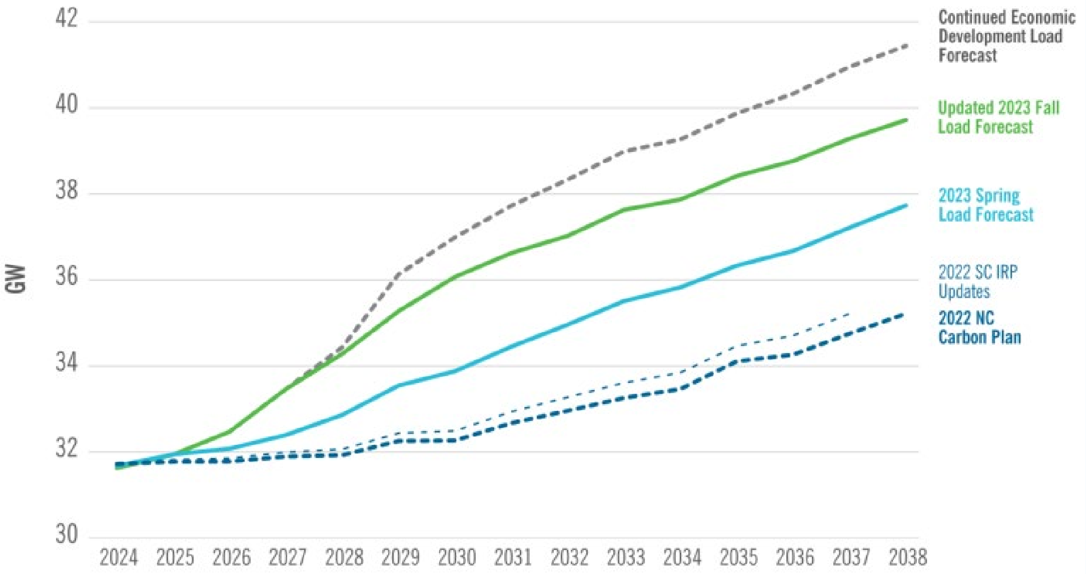
Duke Energy owns two operating companies in the Carolinas: Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP). Each serves portions of both North and South Carolina. The Duke Energy planning area also includes several public power utilities.

While Duke Energy's 2021 load forecast showed little growth from 2024 to 2028, in Spring 2023 it added about 1 GW and then in November it announced an additional GW in growth over the next five years. These growth expectations are driven by large site developments. **Duke reports that this increase is attributable to the anticipated development of data centers, vehicle manufacturing, battery production, and associated supply chain "mega-projects."**

Notably, when adding "mega-projects" to its 2023 forecast, Duke applied a "discount" of 30%-60% to its full load expectation for each individual development site to account for uncertainty and avoid double-counting.

In comparison, Duke has not changed its near-term view of load impacts from EV charging and other trends affecting residential and commercial classes.

Figure SPA 1-1: Load Forecast Evolution, 2021 to 2023 Carolinas Combined DEC and DEP Non-Coincident Winter Peak at the Generator



SOURCES | Duke Energy's Integrated Resource Plans (IRPs), including the DEC 2020 (p. 238), DEP 2020 (p. 229), Duke Carolinas 2022 - Appendix F (pp. 20-21), Duke Carolinas 2023 - Appendix D (pp. 13-15, 25), Glen Snider Supplemental Testimony (pp. 5-9), and Supplemental Analysis, Jan 2024 (p. 5).

Load Forecasts May Be Catching Up With Data Center Load Growth

Data centers currently represent 2.5% of U.S. electricity consumption

By 2030, BCG expects energy use to grow from 126 TWh to 335 TWh, or demand of 17 GW to 45 GW

GenAI is a significant driver of BCG's estimate:

2 GW of GenAI-related load in the base case

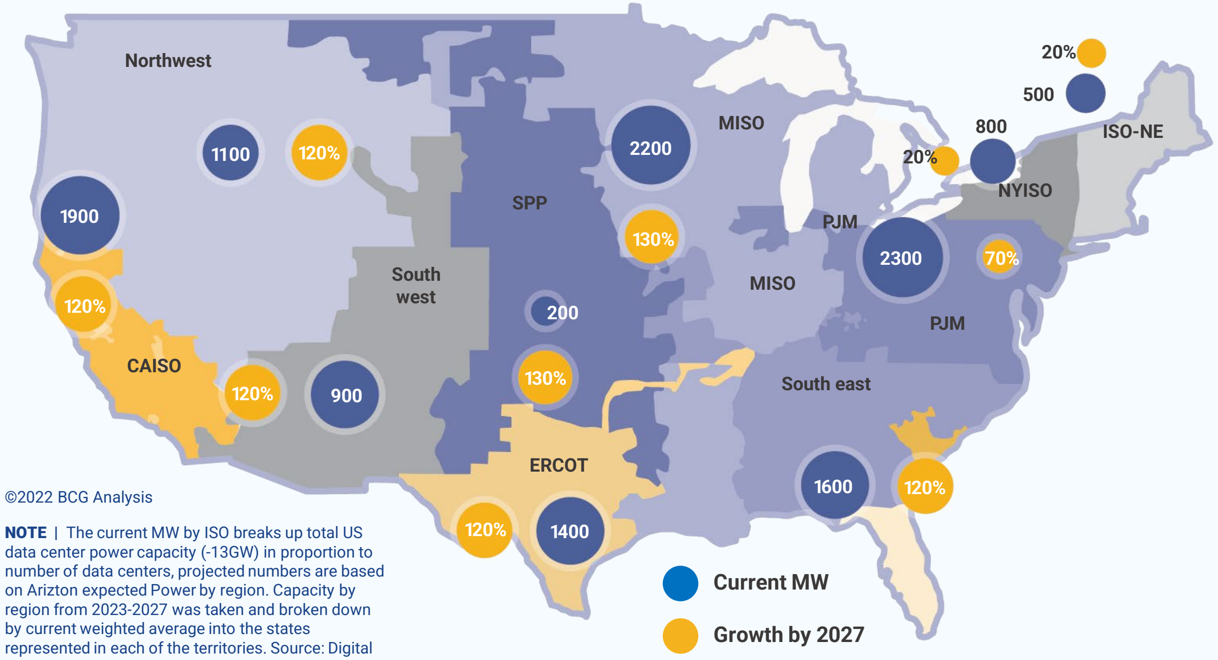
Possibly an *additional* 7 GW of GenAI load online by 2030

BCG estimates that data centers could consume 7.5% of all electricity in the U.S. Other experts at a recent Aspen Institute conference believe the number could reach 10%, including crypto.

Neither MISO nor CAISO's 2023 forecasts appeared to include substantial data center growth

By 2030, BCG expects energy use to grow from 126 TWh to 335 TWh, or demand of 17 GW to 45 GW.

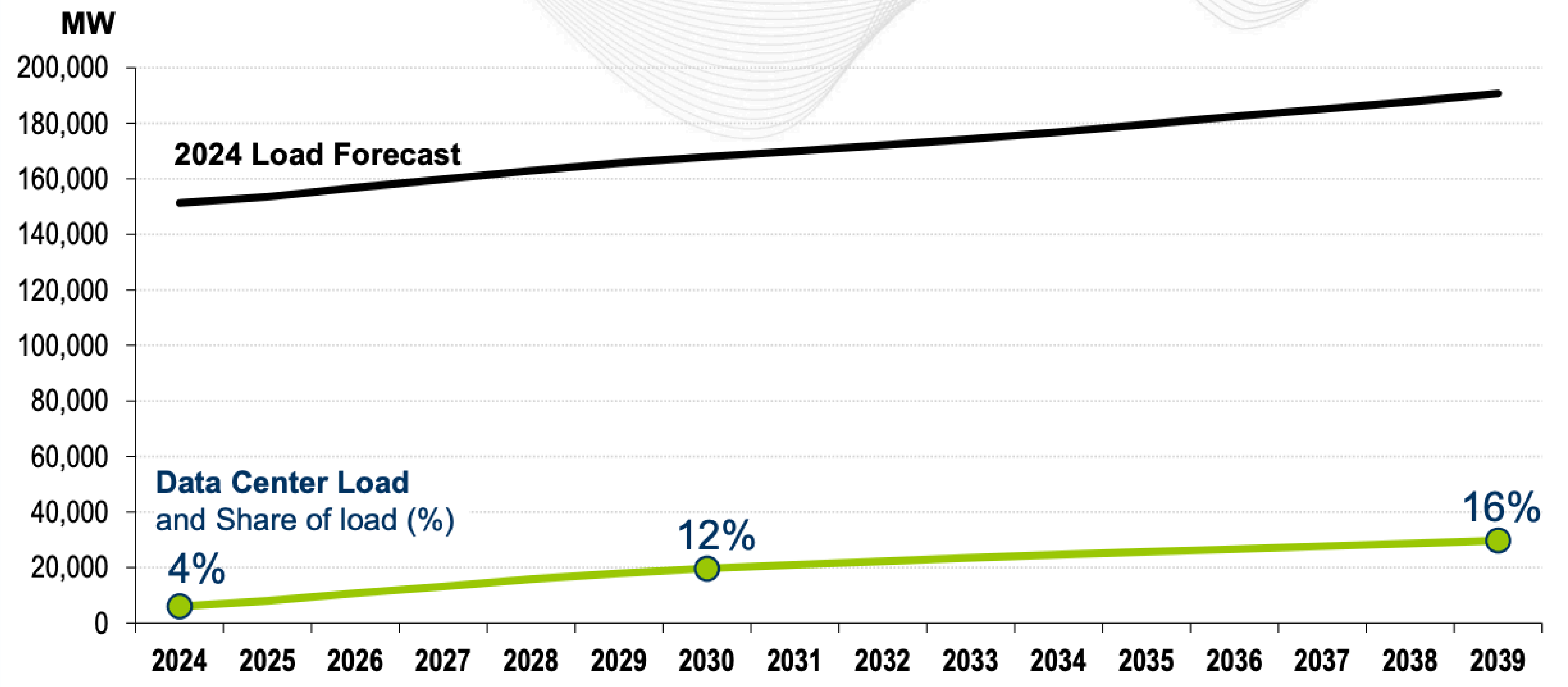
>60% of Data Centers Expected in MISO, CAISO, PJM, and Southeast by 2027



NOTE | The current MW by ISO breaks up total US data center power capacity (-13GW) in proportion to number of data centers, projected numbers are based on Arizton expected Power by region. Capacity by region from 2023-2027 was taken and broken down by current weighted average into the states represented in each of the territories. Source: Digital Infra Real Estate, Omdia, Anzton, BCG Analysis

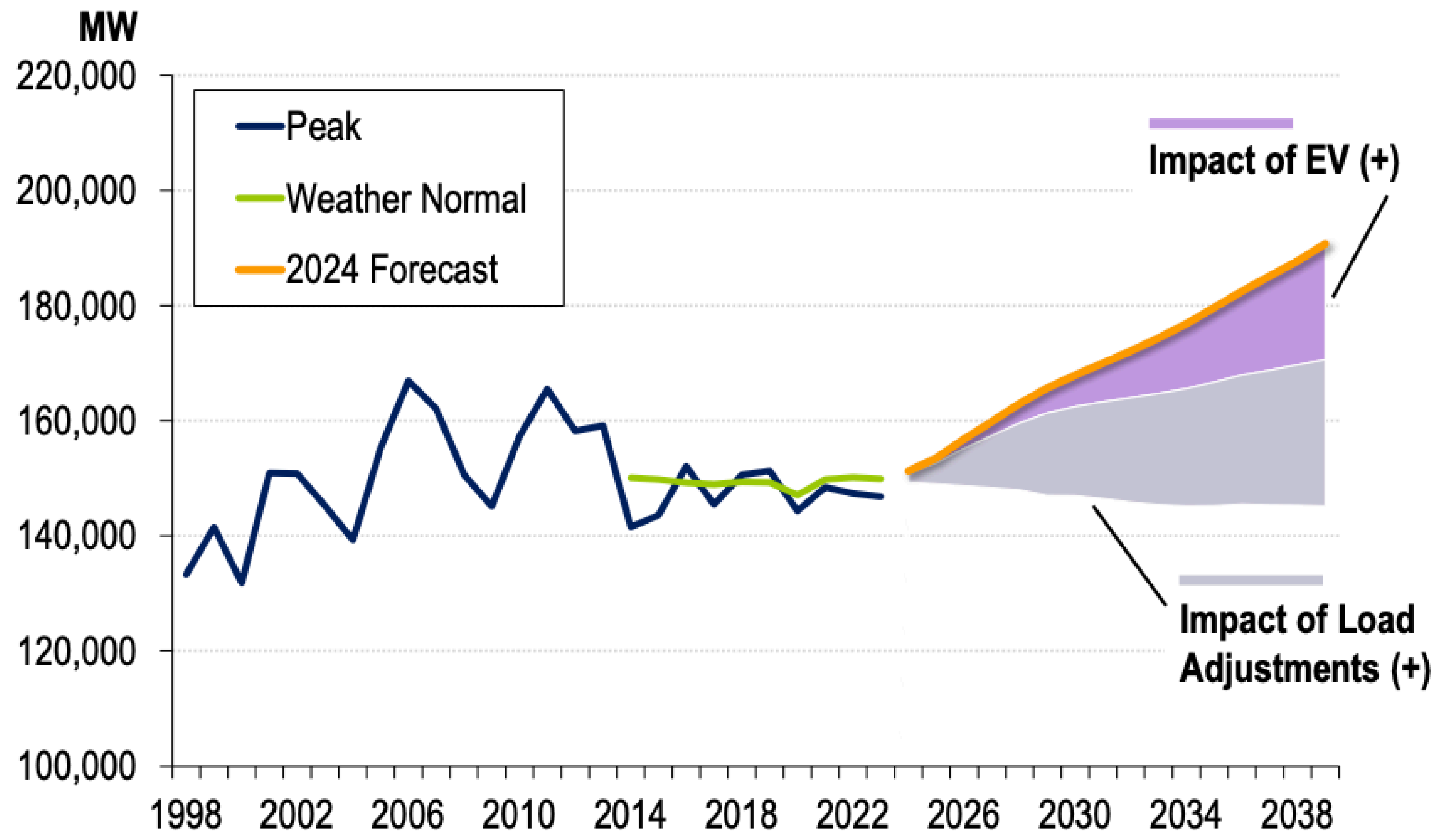
SOURCES | Arizton, *US Data Center Construction Market – Industry Outlook and Forecast 2023-2028* (February 2023).
Avelar, Victor et. al., *The AI Disruption: Challenges and Guidance for Data Center Design* (September 2023).
Boston Consulting Group, *The Impact of GenAI on Electricity* (September 2022).
JLL, *North America Data Center Report* (H1 2023).
Mordor Intelligence, *U.S. Data Center Construction Market Size* (2023).

PJM's Data Center Load Growth



SOURCE | PJM, *Load Forecast Development & Use in PJM*, (June 2024), p. 9.

Impact of Electric Vehicles and Large Load Adjustments



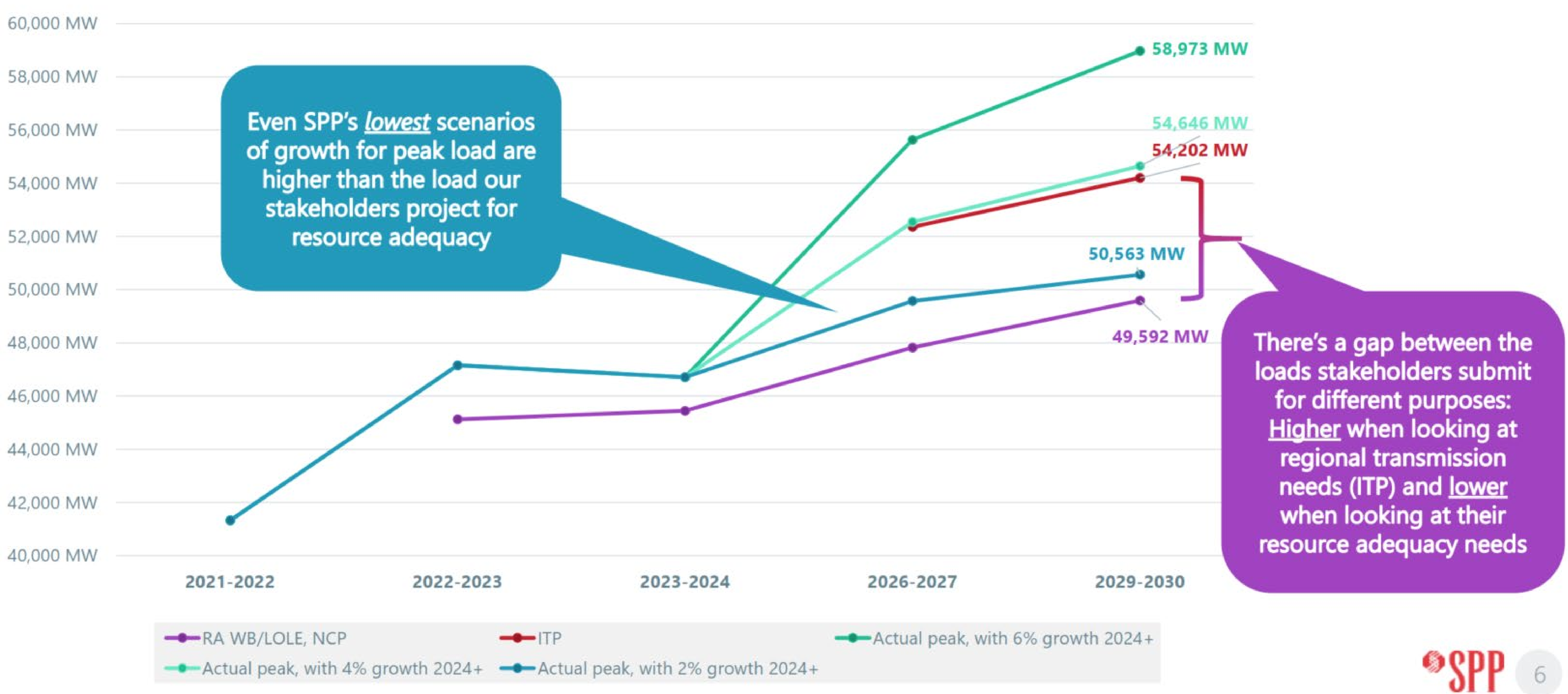
Electric vehicles and large load adjustments **support** load growth.

- Without these trends, 15-year average load growth would be 1.8 percentage points slower (1.6% vs -0.2%).
- The growth drivers are split roughly 60/40 between large load adjustments and electric vehicles, respectively by the end of the forecast.

GridStrategies

SOURCE | PJM, *Load Forecast Development & Use in PJM*, (June 2024), p. 7.

WINTER LOAD FORECASTS: MEMBER-SUBMITTED COMPARED TO ACTUALS AND GROWTH SCENARIOS



SPP

AEP OHIO

Requiring Financial Buy-In from Data Centers

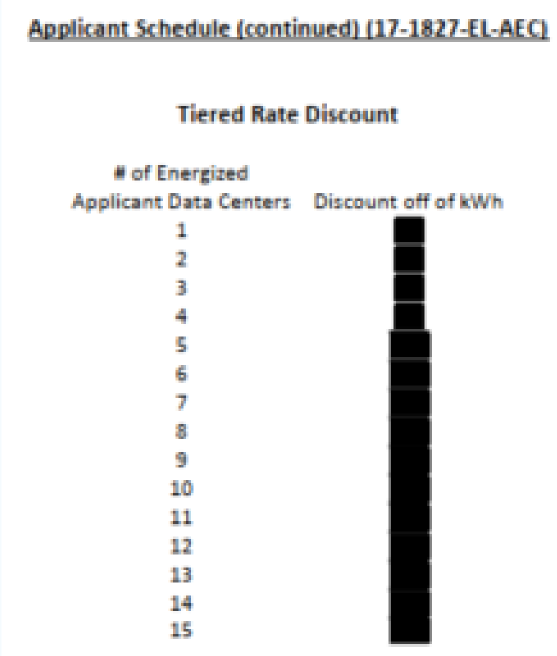
In 2018, Ohio's utility regulator approved a rate discount for Amazon that was supported by AEP Ohio.

In a high-demand environment, utilities are now hesitant to make large investments to support load – especially if it might not remain online.

Utilities may be **facing capital constraints** – or they may be under pressure from regulators to **protect existing customers** from the risk of load departure.

- AEP Ohio has accepted 4.4 GW of new data center load through 2030, this load can be **served without new transmission build-out**.
- AEP Ohio then paused new service requests after receiving 30 GW of requests from data centers.
- AEP Ohio's proposed tariff would **require greater financial commitments** from new data centers with loads >25 MW**. Ten-year contracts** and higher demand charges.
- Some parties have challenged the proposed tariff, arguing that it is discriminatory towards data centers.
- AEP has proposed other approaches in Virginia, West Virginia, and Indiana that apply to all customers with loads >200 MW (>150 MW in Indiana).

2018: AEP Ohio and Amazon Data Center Rate Discount



Applicant Schedule (continued) (17-1827-EL-AEC)

Tiered Rate Discount

# of Energized Applicant Data Centers	Discount off of kWh
1	[redacted]
2	[redacted]
3	[redacted]
4	[redacted]
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12	[redacted]
13	[redacted]
14	[redacted]
15	[redacted]

SOURCES | AEP Ohio, Application for Approval of New Tariffs by Ohio Power Company (filed May 13, 2024); Amazon Web Services, Testimony on Economic Development Arrangement (filed November 7, 2017) Brendon J. Baatz (Google LLC), Testimony on New Tariffs by Ohio Power Company (filed August 29, 2024).

ERCOT

Large Load Forecast Challenges

In 2024, ERCOT's load forecast for 2029 is 88.1 GW, but ERCOT also has **contracts** for large load that would **add ~15 GW** to its summer coincident peak.

There is even further upward growth potential, with **new loads in ERCOT's queue currently total 56 GW**!

ERCOT is proposing to require large loads to be identified by category to improve load forecasting and operator visibility.

ERCOT has temporarily dropped proposals that would have required large loads to provide information on **demand and price responsiveness** to ERCOT, demonstrate capability to ride-through low-voltage events, and other load flexibility requirements.

Currently ERCOT's transmission providers project **66 GW of flat load and 4 GW of price-responsive load** over the next 10-15 years.

2024 ERCOT Large Load Queue

SOURCES | ERCOT, Large Load Interconnection Status Update (September 6, 2024), p. 3.
ERCOT, NPRR1234 – Overview and Key Concepts (August 20, 2024), p. 3-4.
ERCOT, Large Loads – Impact on Grid Reliability and Overview of Revision Request Package (May 6, 2024), p. 7-10.
ERCOT, 2024 Long-Term Load Forecast with Application of New Waterfalls (August 13, 2024), p. 7.

Thank you!

John D. Wilson
Vice President
jwilson@gridstrategiesllc.com

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WECC

NERC LLTF: Whitepaper on Characteristics & Risks of Emerging Large Loads

Katie Rogers – WECC, Manager, Reliability Assessments
Kyle Thomas – Elevate Energy Consulting, VP Engineering/Compliance Serv

October 8, 2024

WECC Large Load Risk Assessment

- A better understanding of large loads and their potential impacts on BPS reliability
  - Increased WECC regional knowledge and understanding of large loads and their developments & impacts on the western grid
- Feedback and concerns from WECC members on this topic, which can help shape the direction/strategy and address identified gaps and challenges
- Information obtained through literature review regarding industry activities, best practices, risks/challenges, actual system events, and more
- Closer collaboration and information sharing within the WECC region on this topic
- A technical report on the assessment of large loads in the West

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WECC LL Industry Advisory Group

- Very informal group, meeting monthly
- Collaborate and share information:
  - Highlight the large load categories and growth in the WECC region
  - Discuss issues/concerns with large loads
  - Identify new and best practices for large load interconnections
- Help shape direction and strategy for the assessment and for WECC as a whole

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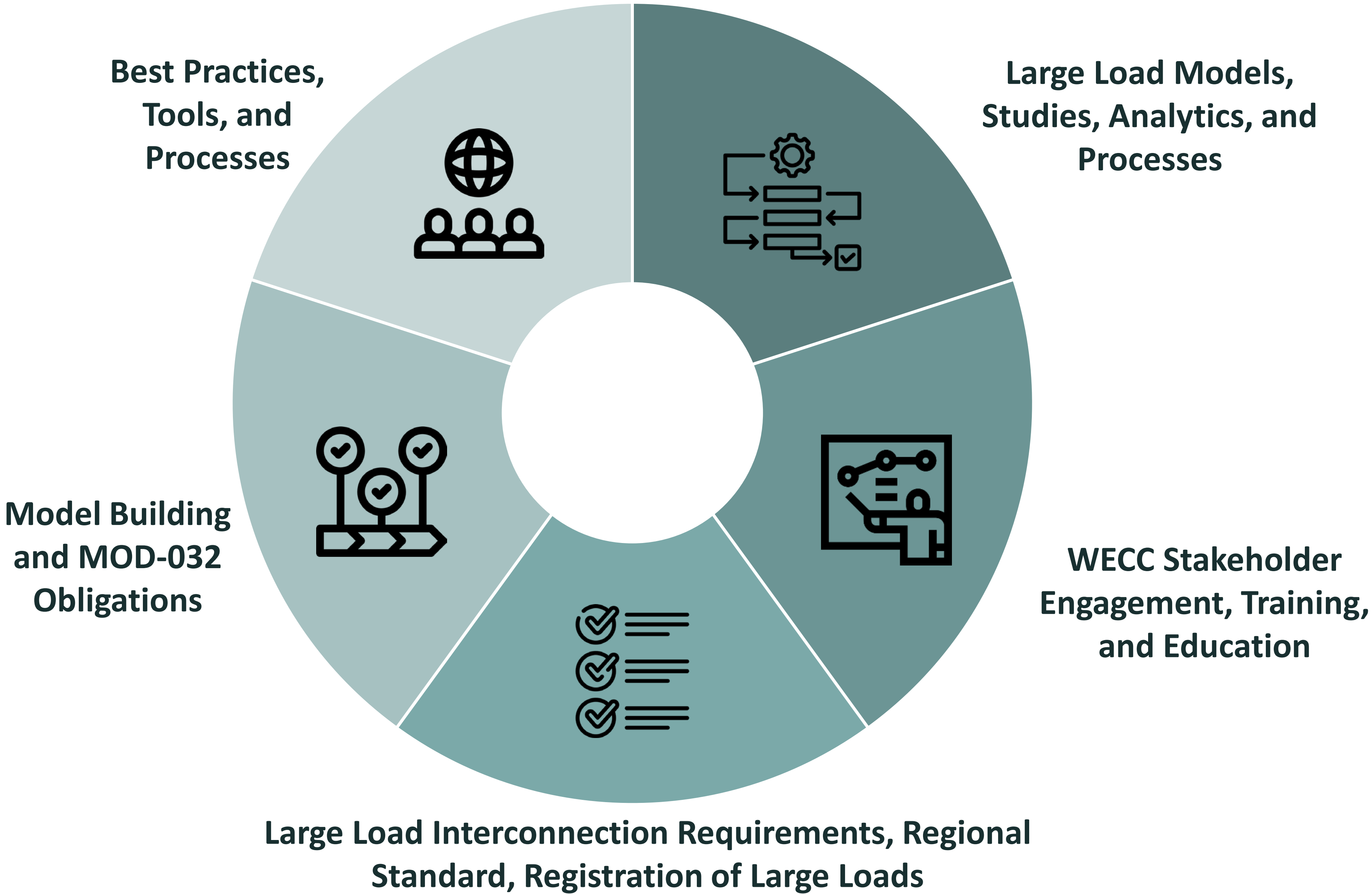
WECC Large Load Topic Areas



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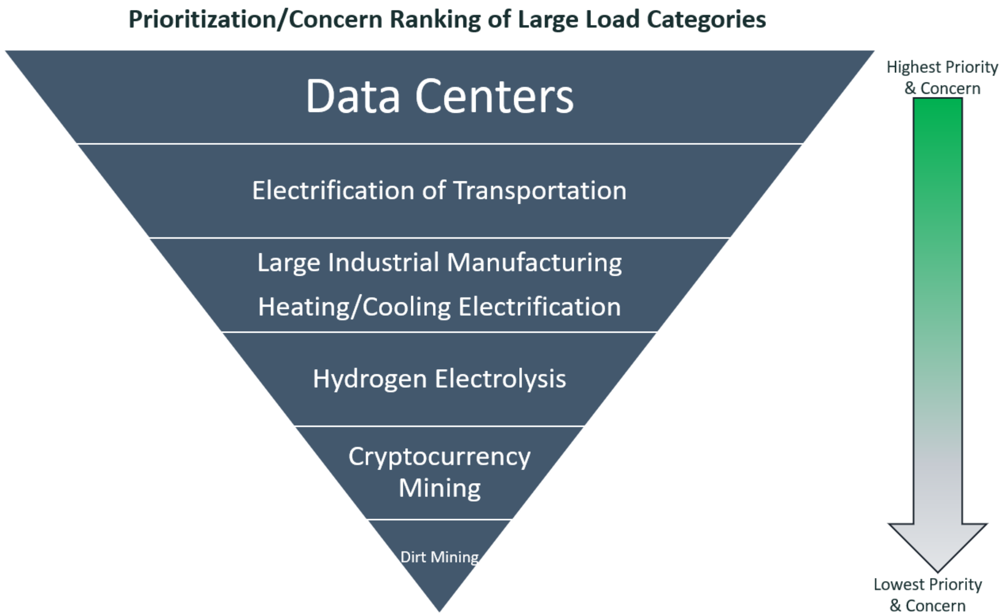
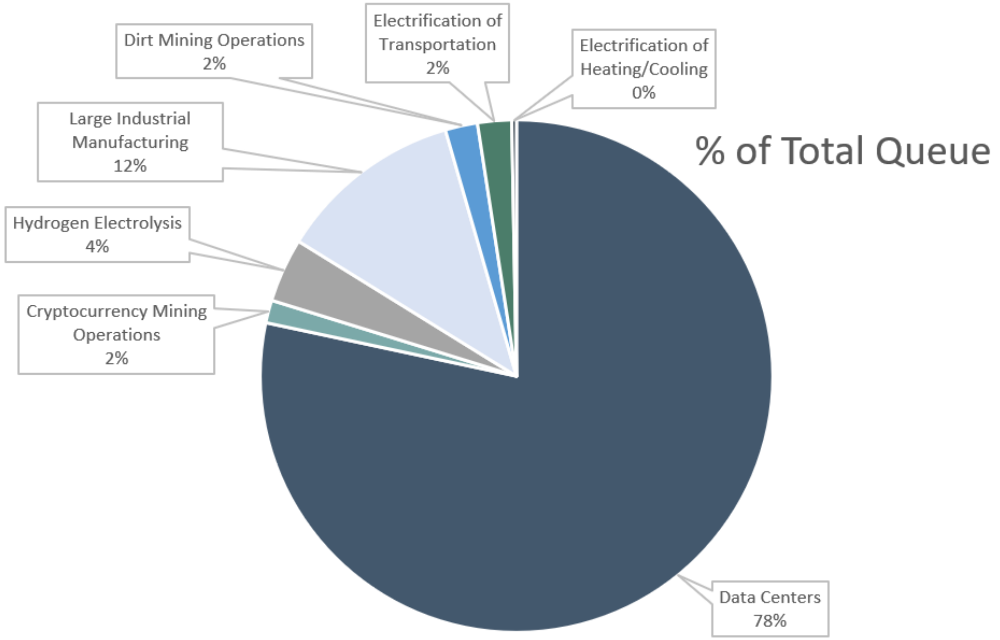
Collected Data from WECC IAG

	10 WECC Utilities	Total Peak Load 43,927
Load Type	Current Estimate of Interconnection Requests (MW)	% of Total Peak Load
Data Centers	34,893	79
Large Industrial Manufacturing	5,211	12
Hydrogen Electrolysis	1,800	4
Dirt Mining Operations	908	2
Electrification of Transportation	955	2
Cryptocurrency Mining Operations	638	1
Electrification of Heating/Cooling	132	0
Total Queue MW	44,537	





WECC Large Load Technical Challenges & Risks

- **Accurate model representations of new large loads (steady state & dynamic)**
- **Interconnection requirements**
- Transmission adequacy
- Oscillation monitoring
- Contingency planning
- Demand response and energy emergency response for large loads
- **Ability to forecast – long-term and short-term**
- Ability to schedule
- Ability to control / dispatch
- Data Center architecture/generation resources BTM (ex: microgrids)

- **Interconnection processes / queue / speed / timeline**
  - Lead time for transmission infrastructure
- Operating characteristics
  - **AI-Load Ramping / “jitter” / “choppy”**
  - **Ride-through**
  - **Voltage and frequency impacts**
- Quality/priority of service requirements
- **Power quality**
- Visibility
- Outage management
- Load factor (% uptime)
- Production cost modeling / resource planning

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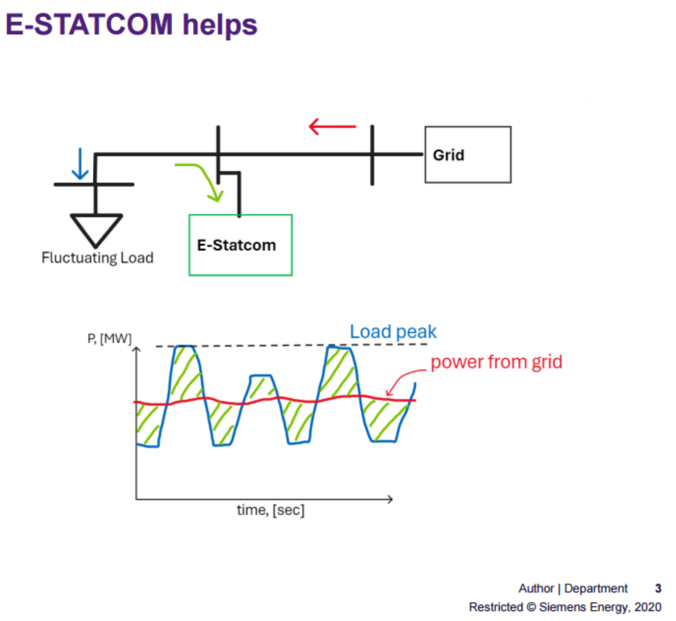
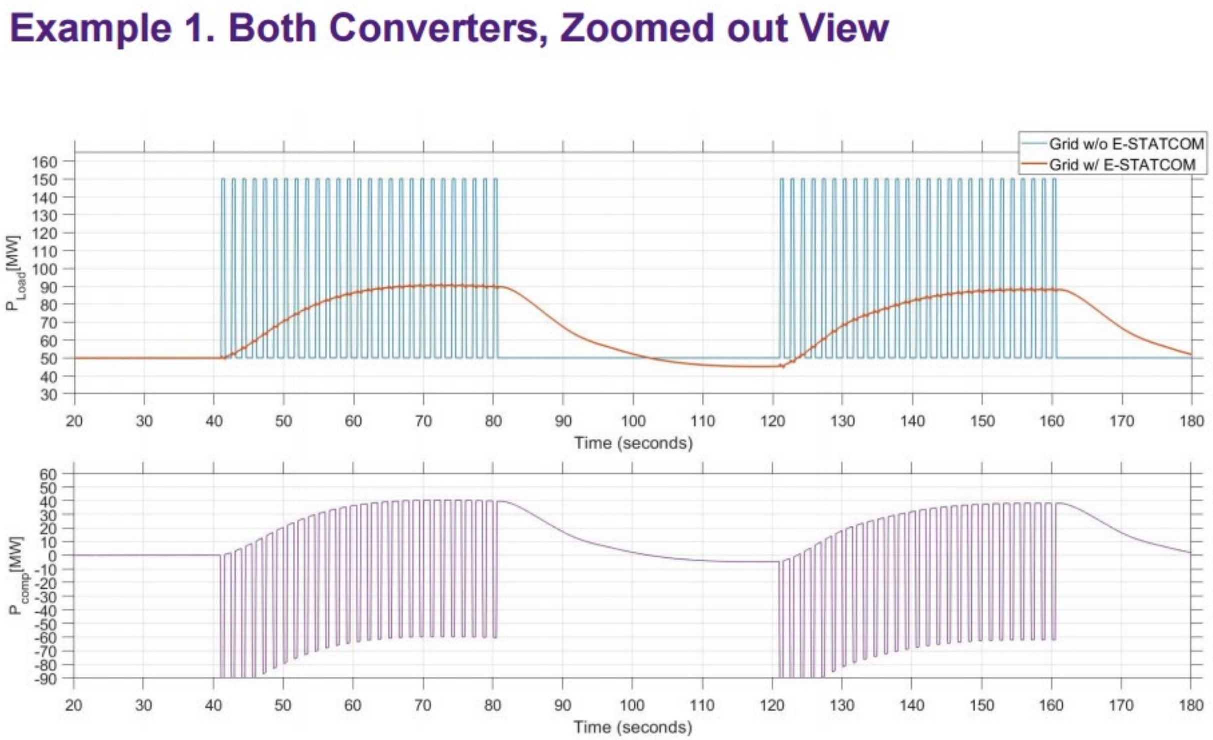
Operating Characteristics

- Some utilities are starting to see sub-second ramping of data center loads from “AI” data centers or AI training runs at traditional data centers
- Utilities are seeing it when looking at power quality meters, DFRs, waveform data, etc.
- New solutions are being explored
  - One shared recently was an E-STATCOM that has a supercapacitor bank to handle the sub-second ramping (fast charge/discharge capability, high power)





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Large Load Interconnection Requirements

- EU has established a Network Code on Demand Connections[1,2]

> System security cannot be ensured independently from the technical capabilities of all users. Historically, generation facilities have formed the backbone of providing technical capabilities. However, in this regard, demand facilities are expected to play a more pivotal role in the future. Regular coordination at the level of the transmission and distribution networks and adequate performance of the equipment connected to the transmission and distribution networks with sufficient robustness to cope with disturbances and to help to prevent any major disruption or to facilitate restoration of the system after a collapse are fundamental pre-requisites.

1. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1388
2. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.223.01.0010.01.ENG#d1e307-10-1

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Large Load Interconnection Requirements

- EU has established a Network Code on Load Connections
  - Different requirements for transmission-connected loads & distribution-connected loads
  - Information/Data exchange requirements
  - Loads must specify voltage & frequency ranges, ride-through for voltage and frequency disturbances, etc.
  - Demand response requirements
  - Automatic disconnection settings shall be agreed between the TSO/the load owner
  - Short circuit requirements
  - Reactive power requirements
  - Protection requirements
  - Control requirements (isolated operation; damping of oscillations; automatic reclosing; automatic switching to backup generation and restoration to normal grid connection)
  - Power quality
  - Model sharing requirements from the load owners
  - Limited operational notifications

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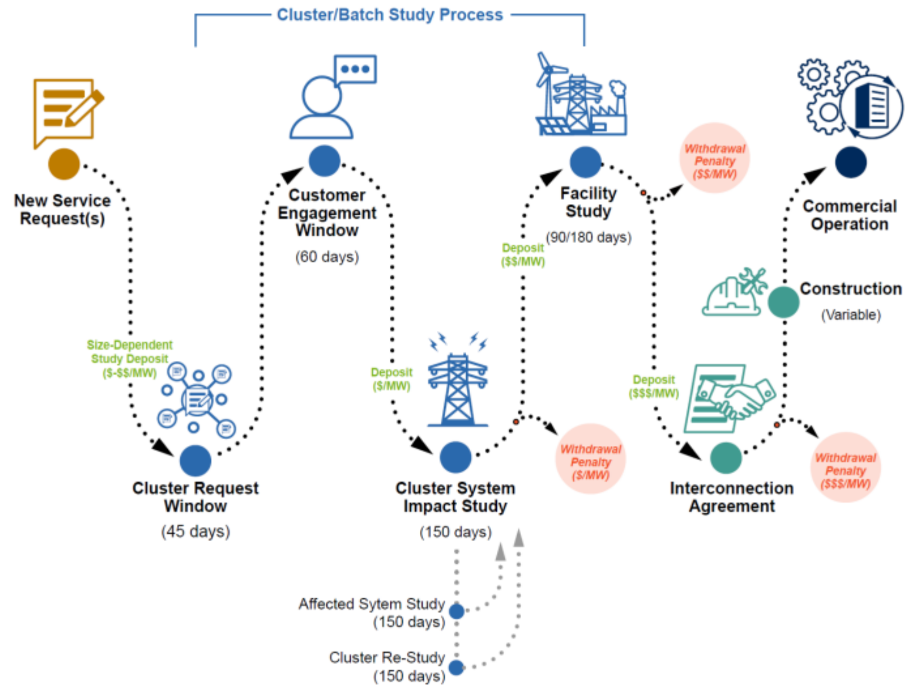
1. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1388
2. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.223.01.0010.01.ENG#d1e307-10-1

Large Load Interconnection Process Improvements

- Hearing that the load interconnection processes and queues need improvements
  - Some places the load queue submittal process is as simple as an email to the Load Interconnection / Transmission Planning teams, leading to study work for any project no matter the level of speculative
  - Load interconnection processes vary widely
  - How to ensure valid real projects move through the interconnection process?
    - Site control requirements, submittal fees for various milestones, etc.
- Can we learn from FERC Order 2023 that overhauled the Generation Interconnection process?
  - Can that be applied to load interconnections?



FERC Order 2023 Generation Interconnection Process

Source: LBNL

https://emp.lbl.gov/sites/default/files/2024-04/Queued%20Up%202024%20Edition_R2.pdf

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NERC LLTF: Task 1 Whitepaper

#	Task Description	Target Completion	Status
1	**White Paper: Characteristics and Risks of Emerging Large Loads** *White Paper on the unique characteristics and risks associated with emerging large loads. This paper will leverage the NERC Framework to address known and emerging reliability and security risks to identify, validate, and prioritize potential reliability risks related to the integration of emerging large loads.*	Q2 – 2025	Not Started

- Open Discussion

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NERC LLTF: Task 1 Whitepaper

#	Task Description	Target Completion	Status
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Call for Volunteers!

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LARGER LOAD TASK FORCE – PHASE 2 WHITE PAPER

Tyler Springer, Manager – Realtime Reliability Engineering

AMERICAN ELECTRIC POWER

WHITE PAPER CREATION

Phase 2 White paper – Identify Gaps and Potential Risk Mitigation

1. **Assess whether existing engineering practices, requirements, and Reliability Standards can adequately capture and mitigate reliability risks identified in Phase 1.**

2. **Identify potential risk mitigations including improvements to existing planning, and operation processes and interconnection requirements for large loads.**

ASSESSMENT OF GAPS FOR EMERGING LARGE LOADS

Brainstorm and Discussion

1. What engineering practices exists for large loads that we can leverage?
   What practices need developed?

2. What interconnection requirements exist for large loads that we can leverage?
   What requirements need developed?

3. What portions of Reliability Standards exist that cover Emerging Large Loads?
   What standard requirements need developed?

RELIABILITY GUIDELINE FOR POTENTIAL RISK MITIGATIONS

Brainstorm and Discussion

1. What improvements to exiting planning and operations processes are needed?

2. What interconnection requirement changes are needed?

3. What improvements can be made to modeling practices, analysis, coordination, realtime monitoring or event analysis?

CALL FOR VOLUNTEERS

PLEASE CONTACT :

Marilyn Jayachandran (marilyn.jayachandran@nerc.net)
Levetra Pitts (levetra.pitts@nerc.net)

Future Meeting Updates

Marilyn Jayachandran, Manager, Advanced System Analytics & Modeling - NERC
LLTF Meeting
October 8, 2024

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Adjourn