ERCOT Experience With Flexibility in Large Loads

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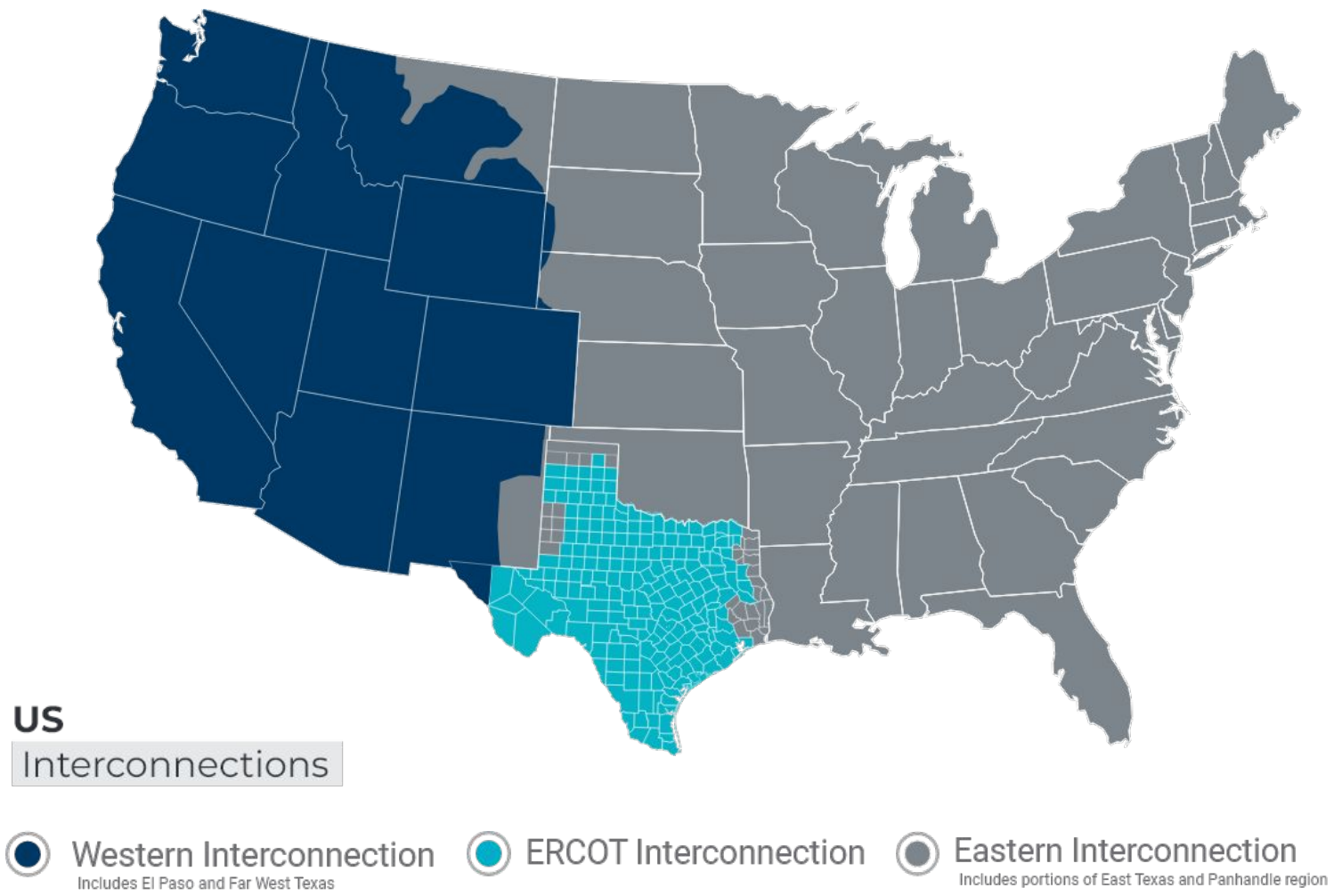
June 13, 2023

Agenda

- Background
- Current large flexible loads – observations and challenges for maintaining reliability
- Needs and solutions for reliable operations in the future

The ERCOT Region



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

- 90% of Texas electric load; 75% of Texas land
- 80,148 MW peak, July 20, 2022
- More than 52,700 miles of transmission lines
- 1,100+ generation units (including PUNs)

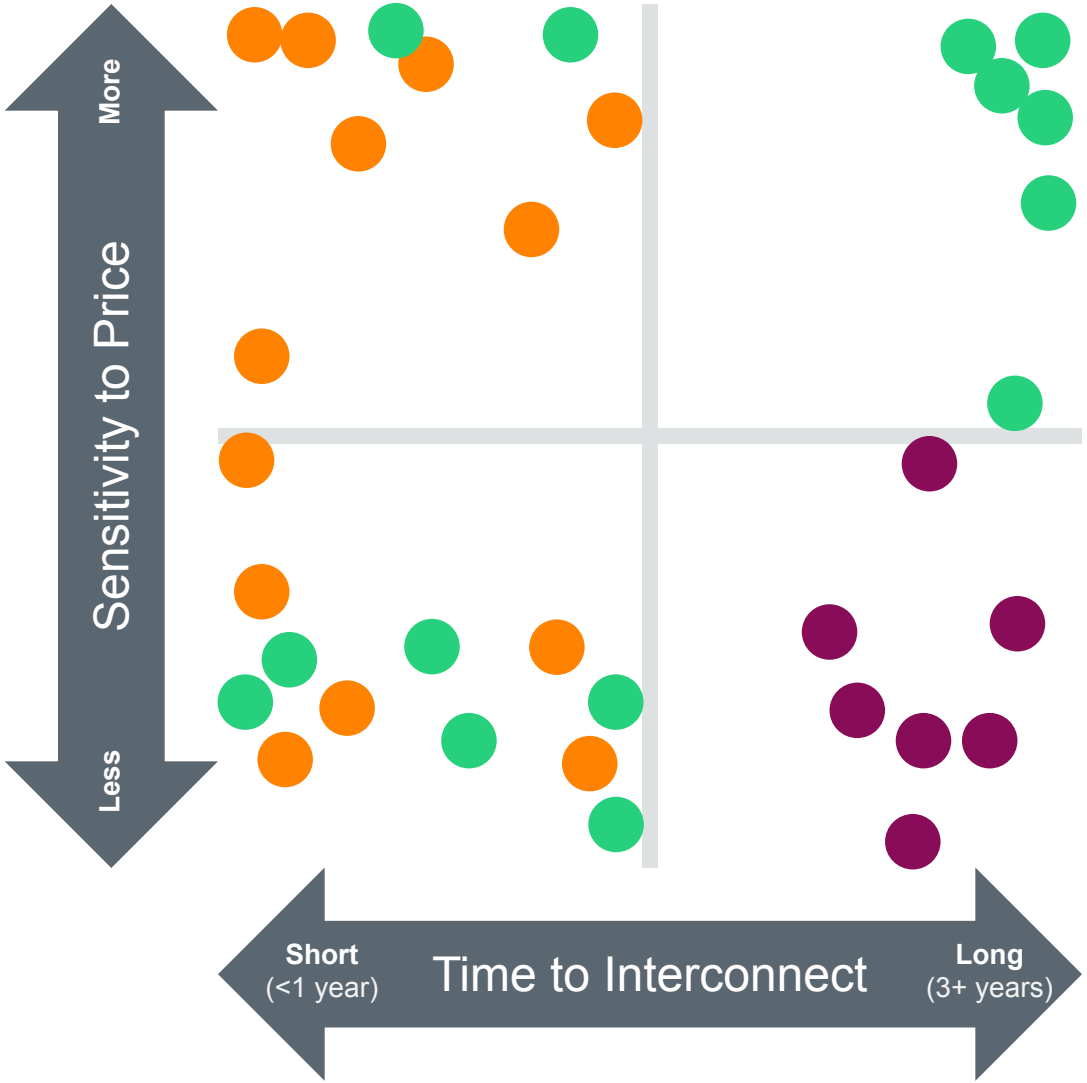
ERCOT connections to other grids are limited to ~1,220 MW of direct current (DC) ties, which allow control overflow of electricity

Large and Flexible Loads - Definitions

- ERCOT considers an aggregate load of 75 MW or greater behind a single point of interconnection to be a **large load**
  - 20 MW or greater if the load is co-located with a generation resource

- 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 SCED
  - Many other flexible loads adjust consumption independent of any direction from or coordination with ERCOT

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

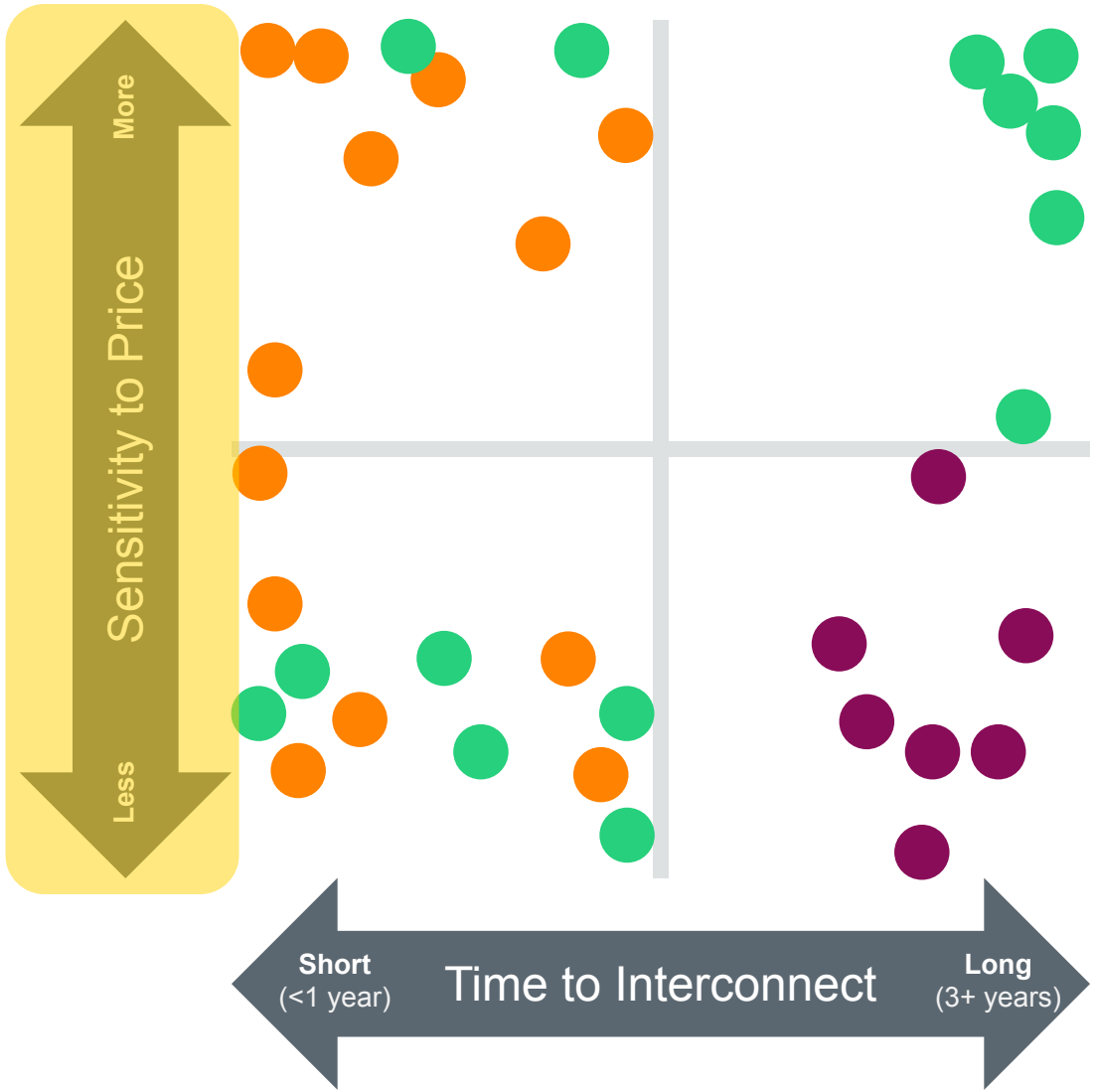
Current Wave of Large Loads

- Mostly cryptomining, data centers, 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, data centers, some cryptomining
- Range of interconnection timelines and price sensitivity

Large Loads Coming to ERCOT



These large loads present 2 distinct challenges

- Very short timelines to interconnect (months rather than years)
  - This is faster than traditional planning processes can accommodate
  - Will be discussed at a later session
- Sensitivity to prices and rapid response times
  - Load can ramp hundreds of MWs in seconds to a few minutes
  - Significant challenge to reliability

Growth of Large Load in ERCOT

- As of May 2023, ERCOT is tracking 41,766 MW of large load via its interim process applicable to loads wanting to interconnect in 2 years or less
  - Not all of this load will ever be built

- Additional large load with interconnection dates further in the future under study by TSPs
  - This includes 10,599 MW of hydrogen and electrofuels production[1]

- ERCOT is also aware of an additional 1293 MW of cryptomining loads smaller than 75 MW in operation or with signed interconnection agreements with TSPs[1]
  - These represent additional flexible loads coming on the system

[1]Based on TSP responses to an ERCOT RFI issued in Nov 2022

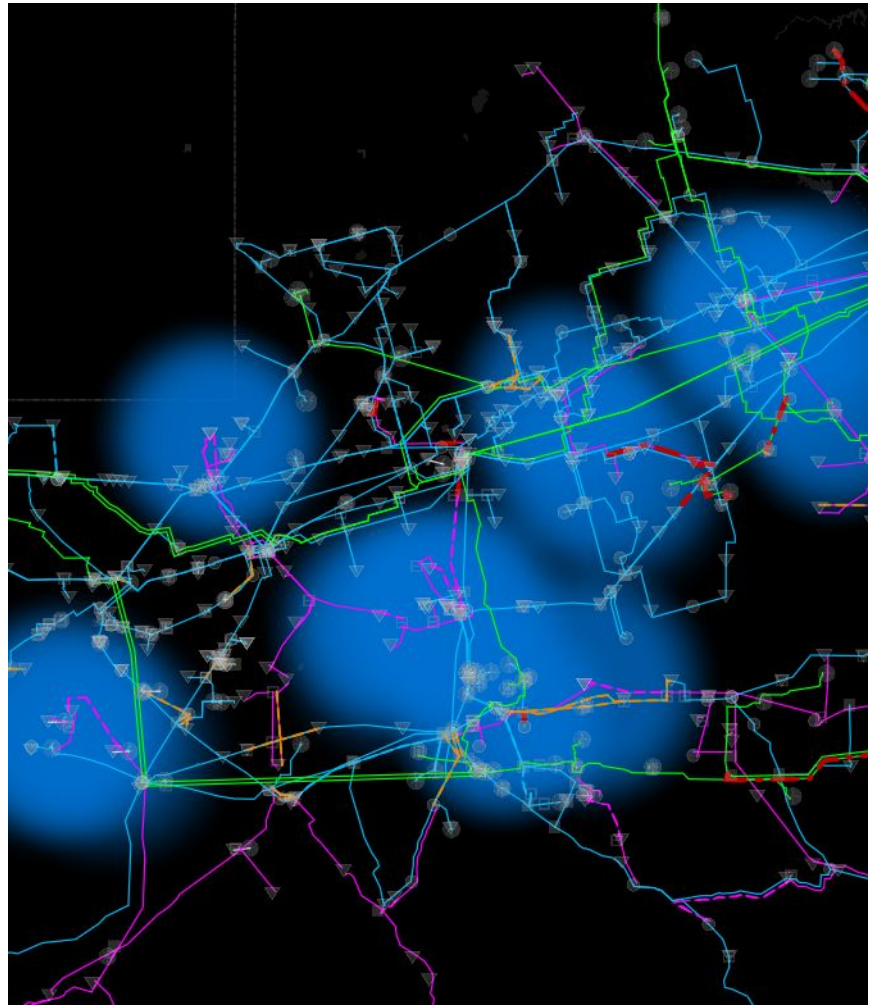
Operational Challenges

- Voltage Ride-Through
- Price Sensitivity and Frequency Control
- Lack of good information – forecasting, reliability studies

Voltage Ride-Through (VRT)

- 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

- Equipment that is not designed to stay online ("ride-through") during the depressed voltage can cause or exacerbate reliability problems
  - Frequency instability
  - Voltage instability (low or high)
  - Other issues



VRT Events

- The ERCOT system has experienced multiple events in the last year that included loads failing to ride-through a voltage depression

- Largest load loss event to-date:
  - Multiple faults on 138 kV lines near Odessa at 3:50 AM on December 7, 2022
  - Reduction in load of ~1,600 MW
  - Load reduction included mix of LFLs, oil/gas load, and other industrial loads
  - Two thermal generators tripped during the event, totaling 112 MW
  - **System frequency spiked to 60.235 Hz**

VRT - Considerations

- Historically, engineers have considered some load reduction/ tripping during a fault/ low voltage as permissible and sometimes preferable, particularly for loads that increase real or reactive power consumption at lower voltages
- However, as the amounts of voltage-sensitive loads increase and system strength decreases, the likelihood of large amounts (GWs) of load loss during a voltage excursion increases, which can lead to frequency instability and potentially other reliability issues
- To address this reliability risk, ERCOT has developed a **proposed** ride-through standard for large loads
- Consideration given to IBR ride-through requirements, CBEMA (1970s), ITIC (1990s), and IEEE 1668 (2017)[1]

1 https://standards.ieee.org/ieee/1668/6798/

Large Load Voltage Ride-Through Standard Proposal (1/2)

Large Loads that interconnect to the ERCOT Transmission Grid must be designed and relays must be set to ride through and continue to consume power for the following operating conditions in Tables A and B, as measured at the Large Load's Point of Interconnection:[1]

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

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

From ITIC Curve

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

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

Based on proposed IBR requirements in NOGRR245

[1]Proposal not yet adopted and may change

Large Load Voltage Ride-Through Standard Proposal (2/2)

Large Loads that interconnect to the ERCOT Transmission Grid and that consist of primarily power electronic equipment and/or variable speed drives must be designed to use constant current control and may not be designed to use constant power level control.[1]

The purpose of this requirement is to prevent loads that are riding-through the voltage excursion from exacerbating the low voltage conditions.

A similar recommendation was made in the NERC-WECC paper on electric vehicle charging performance: https://www.nerc.com/comm/RSTC/Documents/Grid_Friendly_EV_Charging_Recommendations.pdf

[1]Proposal not yet adopted and may change

Operational Challenges

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Price Sensitivity and Frequency Control

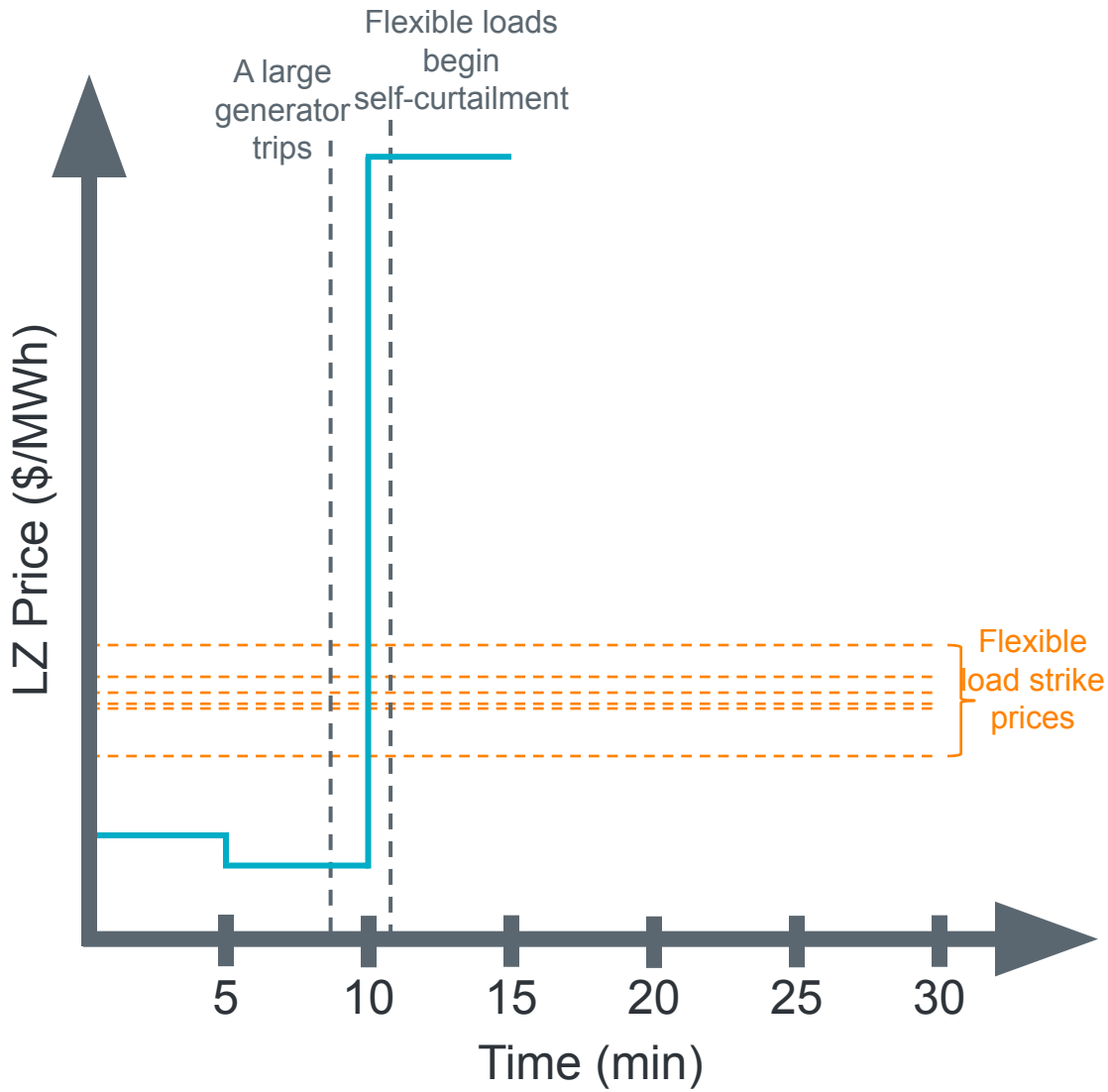
- Vast majority of large loads today do not participate in ERCOT's Security Constrained Economic Dispatch (SCED)
  - Price responsive loads may vary consumption at any time without notice or coordination with ERCOT
  - Flexible load outside of SCED is also not accounted for when the engine issues generation basepoints

- A large spike in price (e.g. due to a generator trip) can potentially trigger hundreds or thousands of MW to simultaneously self-curtail in a matter of minutes

- Since this is not coordinated with ERCOT's dispatch, it poses risks to frequency control and proper dispatch of generation

Price Sensitivity and Frequency Control – Example

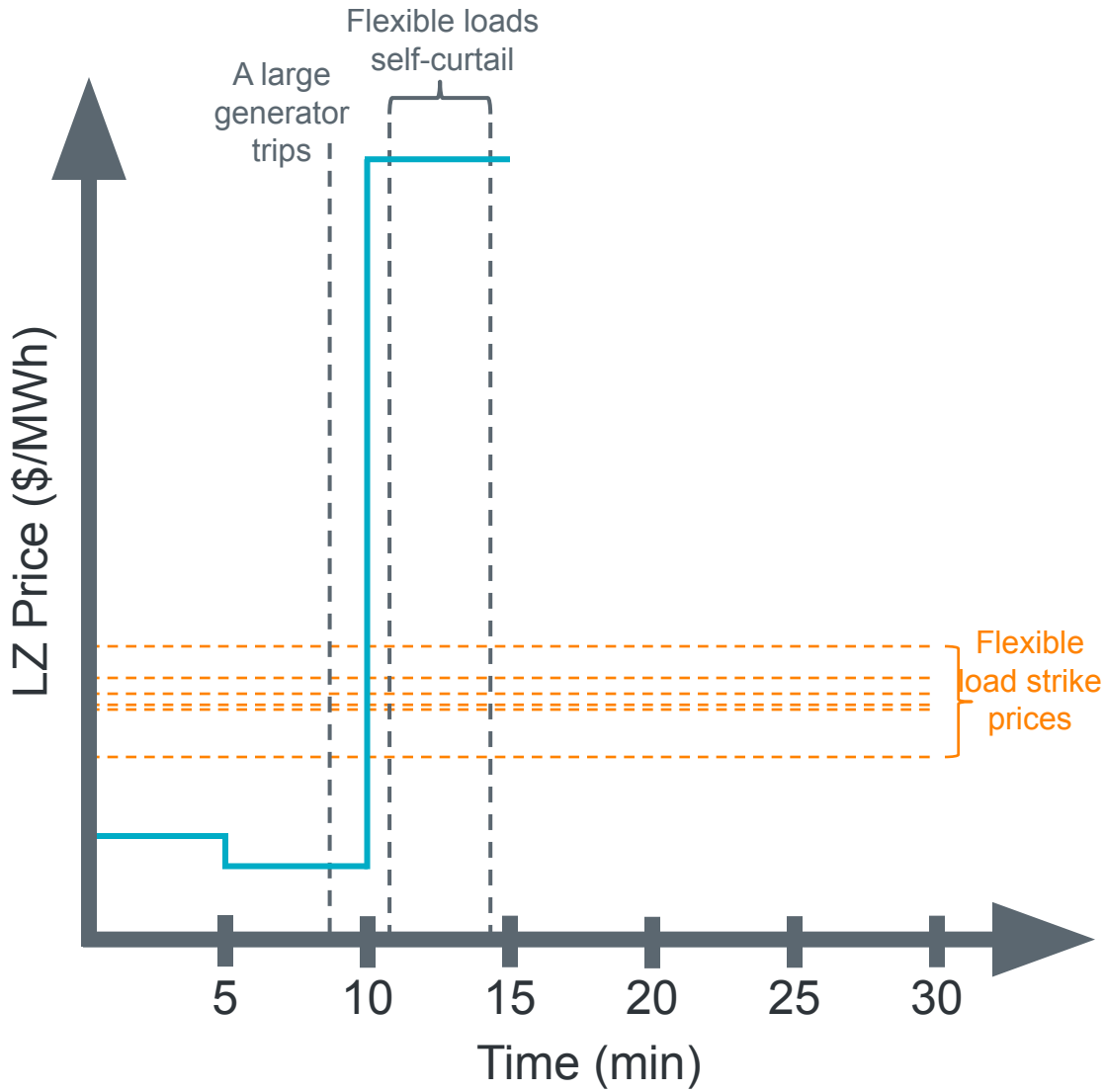
- During normal operations, a large unit suddenly trips
- On the next SCED run, prices spike well above the strike price for a group of large loads
- What happens next?
- Price sensitive loads begin self-curtailment



Price Sensitivity and Frequency Control – Example

Issue 1: Speed and MW amount of self-curtailment will affect frequency

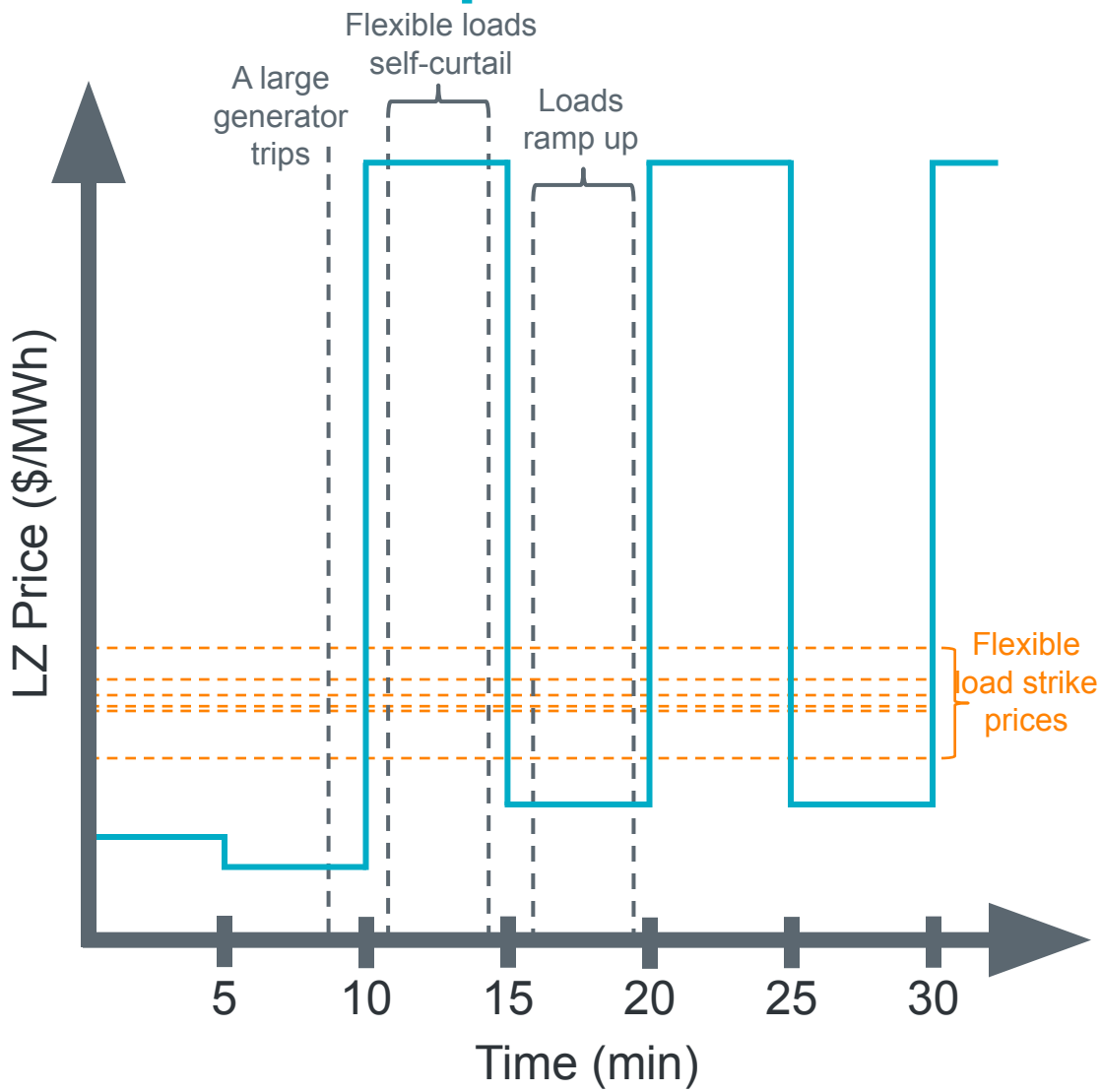
- Many flexible loads can self-curtail in less than 5 minutes
- As more load is added to the grid, thousands of MWs may self-curtail
  - ERCOT procures ~325 MW of Regulation Down on average
  - ERCOT's frequency bias is 895 MW/0.1 HZ
- Since SCED did not account for this behavior, grid frequency will rise



Price Sensitivity and Frequency Control – Example

Issue 2: Large-scale self-curtailment outside of SCED can lead price and generation oscillations

- After flexible loads have self-curtailed, prices likely will drop on the next SCED execution
- This incentivizes flexible load to increase consumption, which may lead to another spike in the next interval
- This pattern negatively impacts generators and other customers



Optimizing Reliability – More Loads Participating in SCED

The optimal solution for grid reliability is for as many large loads as possible to participate in the economic dispatch (SCED) as a Controllable Load Resource (CLR).

Benefits for Loads

- Still free to set strike price(s) via bid to buy curve
- Eligibility to provide AS
- Potential pricing and settlement benefits[1]

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 AS

[1]If proposed language is adopted

Reliability Needs – Loads Outside of SCED

- Limit ramp rates for large loads that elect not to register as a CLR

- Identify additional telemetry and registration data to be collected from large load customers to aid in forecasting

Operational Challenges

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Key Information is Unknown to ERCOT

Interconnection Phase

- Interconnection requests are often for amounts designed to “test” a POI
- ERCOT has no way to distinguish “real” projects from frivolous requests or duplicates
- Unclear timelines for load increases as new equipment is added

In Operation

- Price(s) at which the load will curtail consumption
- Rate at which consumption can be curtailed
- PPAs or other agreements that might impact “flexible” behavior

Questions?