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Large Loads: Interconnection, Planning and Reliability Considerations

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DELIVERING ENERGY INTELLIGENCE

Agenda

1. Large Loads

2.Forecasting and Modeling

3. Planning for Interconnection

4. Operational and Market Considerations

“By failing to prepare, we are preparing to fail”

- Benjamin Franklin

Large Loads

Large Loads Applying to Connect

Data Centers

- Large volume of requests across the continent, concentrated in the mid-Atlantic, Upper Midwest, Texas and California.
- **Size**: 10s-100s of MW

Cryptocurrency Mining

- Large volume of requests across the continent, heavily concentrated in Texas, Southeast and Northeast.
- **Size**: 10s-100s of MW

Electrification

- Transportation, buildings, residential
- **Size:** smaller individually, but aggregate can be 100s of MW

Commercial and Industrial

- Electric Arc Furnaces, Oil and Gas, Ammonia Green Hydrogen
- **Size**: Can be 100s of MW to GW

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Forecasting of Spot Load and Large Loads

Findings from the ESIG Long-Term Load and DER Task Force

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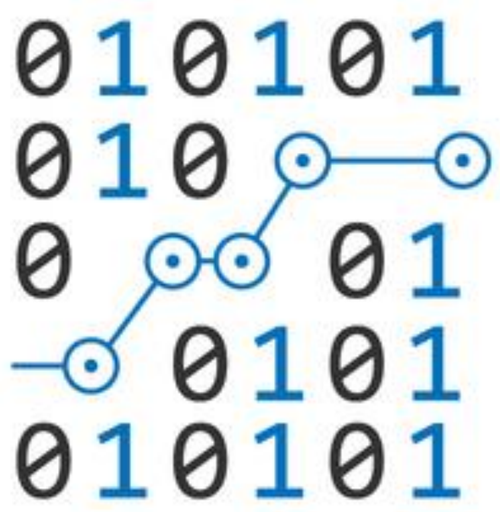
Forecasting Considerations



- **There is no formal forecasting model that is used today to forecast large loads, in particular data centers**
  - Very large (increasing!) binary and heterogenous
  - Drivers change, e.g. distance to fiber-optics network
- **Data informing forecasting is obtained by utilities / ISOs directly from customers and developers seeking to interconnect**
  - Some utilities derate of rated capacity values based on recent experience or for later years*
- **No standardization in data center consumption requirements, interconnection queue, modeling, etc.**

*Utility Experiences and Trends Regarding Data Centers EPRI, Sep 2024

Modeling and Forecasting Concerns

- **Metered versus requested rated power for large loads**
  - E.g. discrepancy between power request and load that shows up
  - E.g. new customer type – land developer only which increases uncertainty
- **Project development timelines are speeding-up**
  - E.g. 1GW data center ramping up to full capacity in less than 12 months
- **Reconciliation of economic load growth and EV forecast with bottom-up new customer service requests**
- **Large increase in new large load requests but uncertainty in what is going to materialize**
  - Little confidence in forecasting for data center loads

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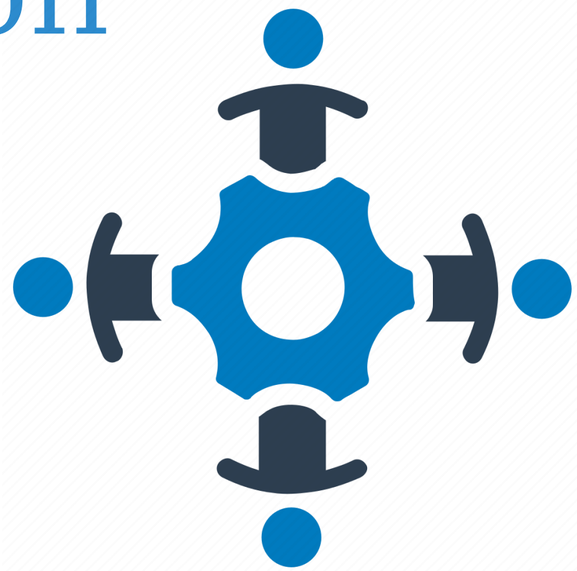
Collaboration and Coordination

Words of the day!



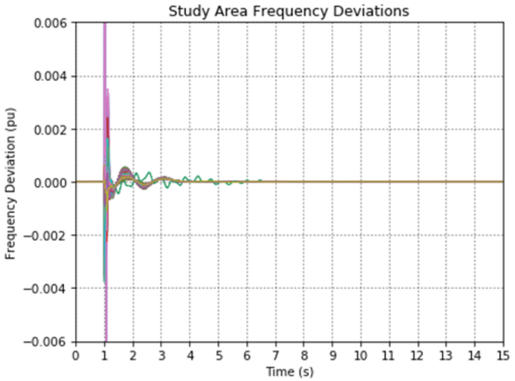
- Federal, state, regulatory, industry, customer and utility **collaboration and coordination** is key to preparing for planning and interconnection of large loads
- Need to develop a **standardized interconnection request** process, improving **planning tools** and models and **standardized framework for load forecasting** with large loads, in particular with data centers

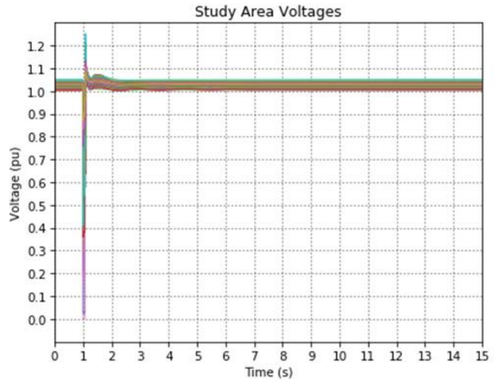
Planning

Planning for Large Load Interconnections

Steady State Studies

- Consider the full amount of load being proposed
- Identifies potential transmission upgrades required to serve full load
- Considers participation type
- For firm loads, require upgrades to consume beyond the level at which overloads or voltage issues occur
- Controllable/dispatchable load resources can connect their capacity up to an overload equal to the short term emergency rating. Given SCED doesn't resolve voltage issues, connections for controllable/dispatchable are limited to level at which voltage related upgrades are required.
- **Need to consider fleet impacts in defining contingencies, may required assessment of large load ramp-ups and downs**





Short Circuit

- Maximum fault currents at the interconnection substation for sizing switching devices and determining relay settings

Transient Stability Studies

- Angular stability, transient voltage stability and frequency deviation assessment

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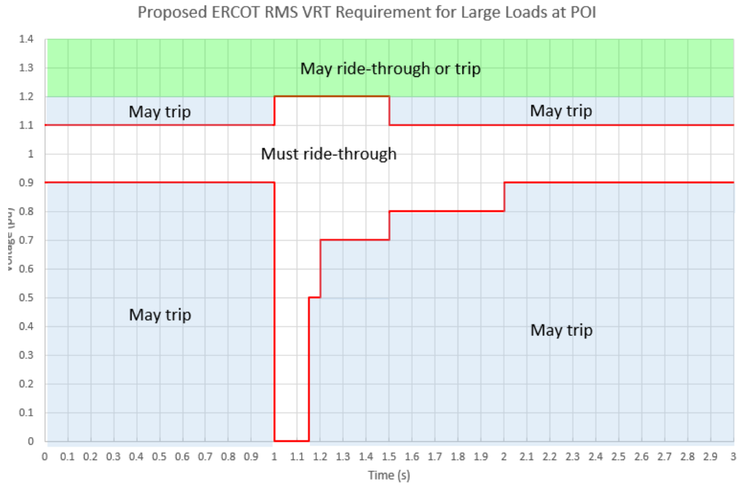
Planning for Large Load Interconnections

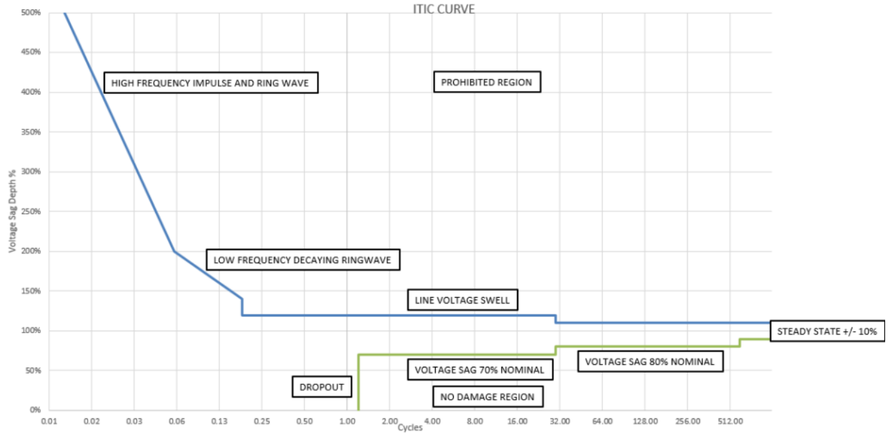
Voltage Ride-Through

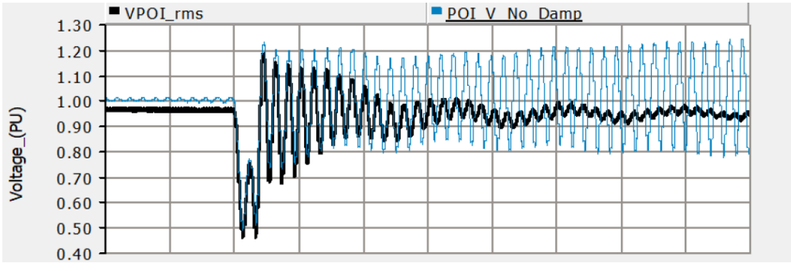
- The unexpected loss of large loads can have significant impacts on system performance, including cascading outages.
- Ensuring large loads are able to ride-through faults outside their protection zone critical for reliability. (e.g. PJM 1,500 MW of data centers were lost)
- ITIC curve (IT equipment tolerance) currently have loads dropping out after one cycle when voltage is below 0.7 pu. Some UPS can help with power conditioning.
- ERCOT has proposed RMS Voltage Ride-Through requirements for large loads

Subsynchronous Studies

- **Ferroresonance**: With incorporation of large transformers on high voltage systems, ferroresonance risks need to be assessed. Risk can be screened based on topology.
- **Resonance**: With transmission upgrades and reconfiguration due to large load interconnections, screening for SSR is required.
- **Controller Interaction**: Required for facilities with SVCs, STATCOMs, other controllers and also heavy motor loads



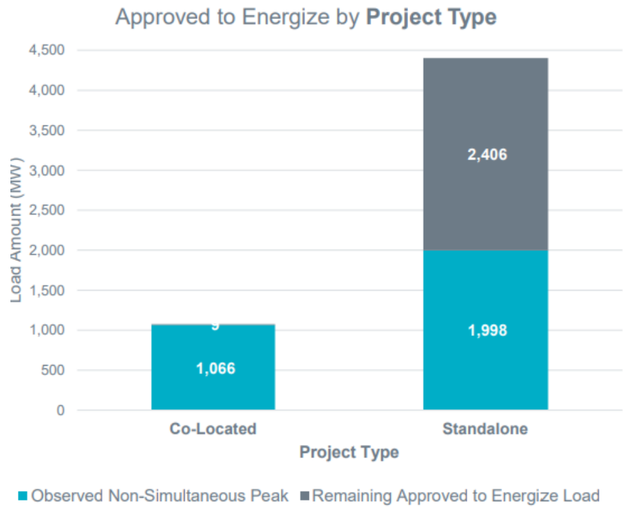




Planning for Large Load Interconnections

Co-located Projects

- With transmission limitations becoming more prevalent with load growth across the continent, co-location of generation and load facilities has become attractive.
- Largely separate generation interconnection and load interconnection study processes have made co-location more attractive
- For example, ERCOT recently approved 5.5 GW of new load, of which ~ 1GW was co-located
- Numerous hyperscalers considering co-locating with SMRs, and even restarting nuclear facilities (e.g. Three Mile Island)



Source: ERCOT LLI Status Update July 2024

Costs and Risks

- Utilities have collectively shared some concerns about the certainty of new data center and other load expected consumption levels.
- In many cases, to integrate these new loads, system upgrades are required.
- To ensure the cost of the upgrade is recovered over an expected time horizon, utilities have tabled a take-or-pay approach (e.g. Duke), capital payments up-front and special rate categories (e.g. AEP).

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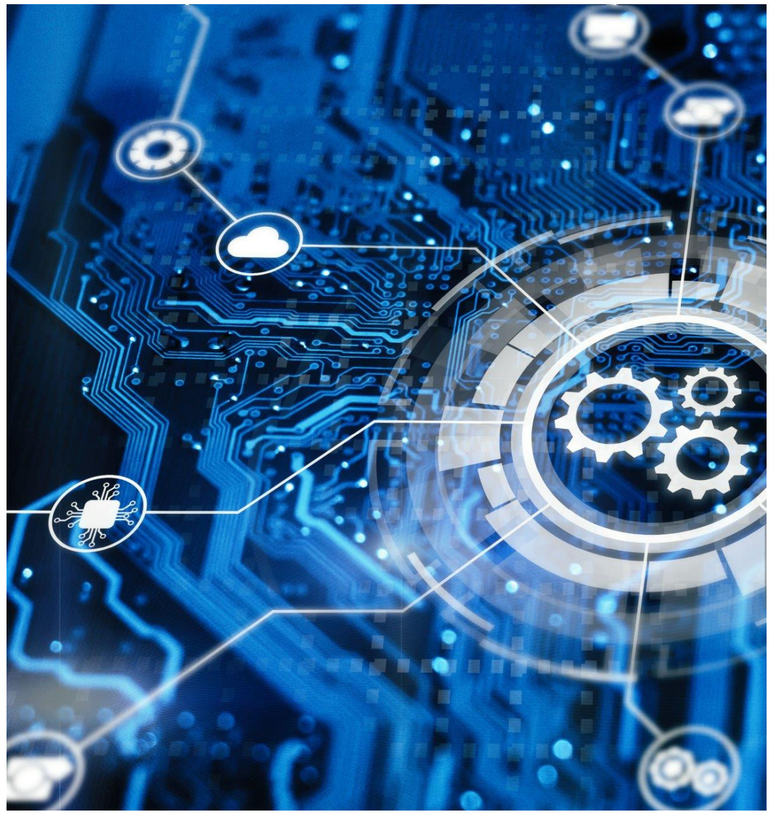
Operations and Markets

Operational Considerations

Operating Philosophy of Large Loads

- Which loads will be passive and which will be price responsive, without being necessarily controllable/dispatchable?
- Will load behavior be impacted by non-traditional factors, such as marginal fuel type? Many tech companies are looking to reduce their carbon footprint and may decide to optimize where they route compute load accordingly.
- Will any potential load shifting affect an entire fleet or only a percentage?
- How will we appropriately model load shifting in EMS and MIS Security Analysis?
- What will be the approach to potential fleet load modelling in advisory schedules that inform unit commitments?



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Load Variability

Ramping and Voltage

- Large load level variability can result in voltage swings which may necessitate including dynamic compensation devices as connection requirements.

Flicker

- Frequency of load and as a consequence voltage change can impact power quality.

Frequency Regulation

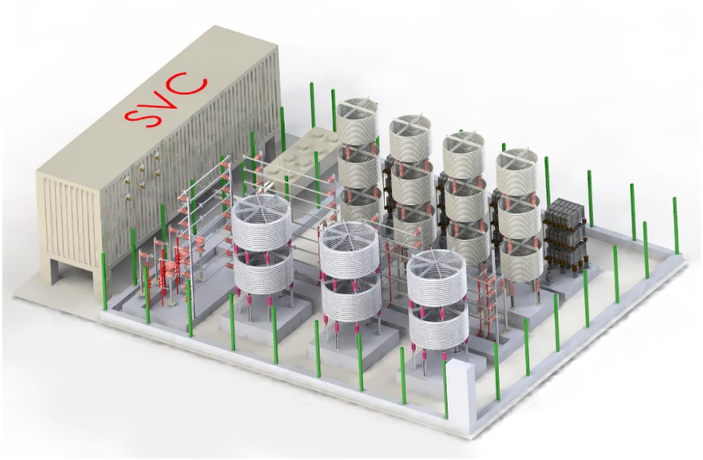
- What are the expected intra-dispatch active power changes that can be expected? How do these expected variations impact the required amount of AGC?

Event/Contingency Modeling

- If there is potential for loads to shift as a fleet, will need to model these events in planning and operational analyses

Forced Oscillations

- Spiking/pulsating nature of some loads can result in forced oscillations when their frequency is near natural modes



Market Considerations

Virtual Transactions

- Virtual transactions are a hedging mechanism that were initially established to increase convergence between day-ahead and real-time market schedules.
- Scheduling algorithms may need to evolve to consider the impact of factors that could influence large load behavior (e.g. external market prices, marginal fuel) to prevent systematic differences between day-ahead and real-time market results.
- When systematic differences are present, virtual transaction related costs can be expected to increase and attract attention of market monitors.

Operating Reserve

- Recently ERCOT reported instances of loads consuming during scarce and high price situations because they were scheduled to provide reserves. This is a counterintuitive outcome and current market design is driving unintended consequences.

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Key Takeaways

Highlights

- Requesting **operating philosophy information**, including **detailed load profiles and expected variability**, as part of interconnection requests will be vital to ensuring the appropriate scenarios are considered and **any requirements/restrictions** on behavior are appropriately incorporated into **Interconnection Agreements**. This will also ensure operations planning understands how to prepare for **real-time, and markets** are designed effectively.
- Planning studies will need to ensure that large loads are able to behave predictably, including r**iding through out-of-zone faults**.
- **Cost allocation** will continue due to potentially high system upgrade costs associate with large loads, and the **risk born by utilities** in undertaking these upgrades without appropriate certainty or collateral.
- **Co-location** will continue to be a theme as the large loads will look to find appropriate means to interconnect as soon as practical.

Questions and Thank You!