UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

North American Electric Reliability Corporation	))	**Docket No. EL25-49-000 AD24-11-000 EL25-20-000**

COMMENTS OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

The North American Electric Reliability Corporation ("NERC") submits these comments in the Federal Energy Regulatory Commission's ("FERC" or "Commission") consolidated proceeding under Docket No. EL25-49-000.[1] NERC respectfully requests that the Commission accept these comments to supplement the record and provide insights into reliability considerations and NERC activities related to large loads connected to the Bulk-Power System ("BPS").

I. INTRODUCTION

As the Commission-designated Electric Reliability Organization ("ERO"),[2] NERC's mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid. In accordance with the Federal Power Act ("FPA") and implementing rules and regulations, NERC is responsible for developing and enforcing Reliability Standards to ensure an adequate level of reliability for the BPS, and for conducting periodic assessments of the reliability and resource adequacy of the BPS.

The Commission began examining the potential implications of co-located large loads in 2024 through two proceedings: a technical conference in Docket No. AD24-11-000, where NERC participated through comments provided by Howard Gugel; and a complaint proceeding under

[1] Pursuant to Rule 212 and 214 of the FERC Rules of Practice and Procedure, NERC submitted a doc-less motion to intervene in this consolidated docket on April 15, 2025.
[2] The Commission certified NERC as the ERO in accordance with Section 215 of the FPA. *N. Am. Elec. Reliability Corp.*, 116 FERC ¶ 61,062 (2006).

Docket No. EL25-20-000. In parallel path as described below, NERC has been in the process of assessing potential reliability implications of large loads interconnected with the BPS. On February 20, 2025, the Commission issued an order to show cause and institute proceedings under Section 206 of FPA regarding large loads co-located at generating facilities ("co-located large loads") in the PJM Interconnection ("Show Cause Order").[3]

Among the issues raised in the Show Cause Order, the Commission referenced NERC's recent analysis and noted the Commission's similar concerns with the potential reliability and resource adequacy implications of co-located large loads.[4] Specifically, the Commission observed:

> We are also concerned about the reliability and resource adequacy implications of co-location arrangements. … NERC also raises concerns about grid-level reliability impacts, noting that, in response to a recent fault on the system, 1,550 MW of voltage-sensitive load (e.g., data centers) disconnected from the system without any action by the utilities, leading to a momentary voltage drop. … We take these reliability concerns raised by [the parties] extremely seriously, and, as such, we are concerned that the [PJM] Tariff … lacks rules necessary to provide PJM with sufficient information to perform appropriate analysis to ensure reliable system operations given the characteristics of co-location arrangements.[5]

The Show Cause Order also consolidated the technical conference proceeding in Docket No. AD24-11-00 and the complaint proceeding in Docket No. EL25-20-000. In addition, the Show Cause Order requests information from interested parties about the reliability and resource adequacy implications of co-located large loads.[6]

Through these comments, NERC seeks to provide insights into its activities examining the implications of co-located large loads and to highlight the benefits and risks to the reliability of the BPS associated with their increasing presence. During the past year, NERC implemented

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[3] *Order Instituting Proceeding under Section 206 of the Federal Power Act*, 190 FERC ¶ 61,115, Docket No. EL25-49-000 (Feb. 20, 2025) [hereinafter Show Cause Order].

[4] *Id.* at P 83.

[5] Show Cause Order at P 83. In addition, *see* Attachment B for further details regarding the disconnection and subsequent rise in voltage, which caused the entity to drop voltage to return to within normal operating levels.

[6] Show Cause Order at pp. 54-55 (in P 88, under e. PJM Capacity Market, Reliability, and Resource Adequacy).

several initiatives addressing large loads, including hosting panel discussions, preparing an insights report on takeaways after a loss of load incident in 2024, and forming a task force to examine the risks and impacts of large loads through whitepapers and guidelines slated for release between 2025-2026. In addition, at the NERC Board of Trustees ("Board") meeting in February 2025, the Board directed NERC to create an action plan to develop industry guidance on large loads, incorporating work by the task force. Further, NERC presented its efforts in these areas at the April 2025 Commission open meeting (**Attachment A**), highlighting several future considerations including potential Reliability Standards, impact studies, and registration activities.[7] Based on these activities, NERC recommends that the Commission and industry continue examining specific reliability implications of co-located large loads. NERC also recommends that the Commission and industry consider requirements for data or information sharing, to support system operators in performing reliability analyses as well as coordination, load balancing, and accurate modeling for co-located large loads. NERC appreciates the opportunity to comment in this proceeding and provide insight into its activities regarding the risks and challenges to reliability posed by co-located large loads on the BPS.

II. COMMENTS

The co-location of large loads with generation facilities can have substantial reliability impacts due to interconnection timelines and loss of loads incidents, while also presenting unique challenges and opportunities for grid transformation. Although any type of interconnection presents similar risks, the size of large loads and their associated impact on power consumption requires special consideration. For example, there is the potential that large loads co-located with

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[7] *NERC Activities and Plans to Address Reliability Impacts from Large Load Integration*, Item A-4, Docket No. AD25-10-000 (Apr. 17, 2025), https://www.ferc.gov/news-events/news/presentation-nerc-seeks-address-reliability-impacts-large-load-integration.

generation could impact resource availability and adequacy. Over the past year, NERC has initiated several opportunities to examine risks and challenges presented by co-located large loads. These include (1) hosting panel discussions highlighting potential risks and mitigation; (2) creating a designated task force under NERC's Reliability and Security Technical Committee ("RSTC"); (3) providing comments for the Commission's large loads technical conference; (4) publishing an incident report on a recent large loads loss incident; and (5) preparing a Board-level action plan to concretely identify and address risks related to large loads.

a. Reliability and Security Technical Committee and Large Loads Task Force

NERC's RSTC is examining the reliability impacts of co-located large loads on the BPS. The RSTC is a standing committee designed to create a forum for aggregating ideas and interests of industry stakeholders, and to leverage that expertise to identify and mitigate emerging risks to the BPS.[8] The RSTC regularly publishes reliability guidelines, security guidelines, technical reference documents, and white papers.[9]

In March 2024, the RSTC hosted a panel discussing the impact of large loads originating from data centers and cryptocurrency mining centers.[10] The discussion highlighted how large loads differ from traditional commercial loads of comparable size, specifically that loads associated with data centers are substantially larger and have shorter timelines for interconnection. The panelists discussed how these types of large loads tend to be highly price-sensitive and experience rapid variations in demand. In addition, panelists discussed how voltage ride-through is a significant concern due to the voltage-sensitive nature of large loads arrangements. In particular, as these

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8 *See* Reliability and Security Technical Committee (RSTC), https://www.nerc.com/comm/RSTC/Pages/default.aspx.

9 *See* RSTC: Reliability Guidelines, Security Guidelines, Technical Reference Documents, and White Papers, https://www.nerc.com/comm/Pages/Reliability-and-Security-Guidelines.aspx.

10 *See* RSTC March 2024 Meeting, Agenda Item 13, Emerging Loads and Electric Vehicles Panel Session (Mar. 12, 2024), https://www.nerc.com/comm/RSTC/AgendaHighlightsandMinutes/RSTC_Meeting_Presentations_March2024.pdf.

centers are designed to maintain steady voltage to protect computer and cooling equipment, even minor voltage changes can cause centers to disconnect from the grid and transfer to backup loads pending manual reconnection to the BPS.

In August 2024, in recognition of these potential reliability concerns, the RSTC formed the Large Loads Task Force ("Task Force") to examine the reliability impacts of large loads on the BPS.[11] The Task Force was assigned responsibility to identify, validate, and prioritize the unique risks associated with large loads. It will also identify gaps and mitigation of potential risks, including any necessary enhancements to aid transmission planners and operators. Over the next two years, the Task Force will produce two white papers and one reliability guideline addressing identification and mitigation of risks, and issue guidance to industry for recommended improvements in modeling, analyses, coordination and data collection, real time monitoring, and event analysis.[12]

The three Task Force deliverables were discussed at the RSTC's 2025 work plan summit and quarterly technical meeting in March 2025.[13] After consideration, the RSTC designated the white papers and guideline as high priority projects due to the potential reliability impacts of large loads.[14] According to this priority, the first white paper will be due in June 2025 and will focus on the unique characteristics and risks associated with emerging loads. A draft of this white paper is currently under review by the RSTC. The second white paper will be due in December 2025 and will assess whether existing engineering practices, requirements, or Reliability Standards adequately capture and mitigate any reliability impacts associated with large loads. By June 2026,

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[11] *See* Large Loads Task Force, https://www.nerc.com/comm/RSTC/Pages/LLTF.aspx.

[12] *See* Large Loads Task Force Scope Document (Aug. 2024), https://www.nerc.com/comm/RSTC/LLTF/LLTF Scope.pdf; *and* Large Loads Task Force Work Plan, https://www.nerc.com/comm/RSTC/LLTF/LLTF Work Plan.pdf.

[13] Available at https://www.nerc.com/comm/RSTC/Pages/default.aspx.

[14] RSTC Agenda Item 5 at 6-8, and Agenda Item 10 (Mar. 12, 2025), https://www.nerc.com/comm/RSTC/AgendaHighlightsandMinutes/RSTC_Agenda_20250312.pdf.

the RSTC will develop a Reliability Guideline to identify risk mitigations and improvements to planning and operations for large loads interconnection requirements.

b. Comments at FERC Technical Conference

In November 2024, as the RSTC's initiatives were underway, FERC held a technical conference to discuss issues related to the co-location of large loads with generating facilities.[15] NERC provided a statement in that proceeding addressing the reliability considerations related to co-locating large loads.[16] In particular, NERC highlighted the importance of planning and coordination to reduce risks, while noting that overall reliability impact will depend on how large loads are implemented, their associated technologies, and any applicable regulatory framework. NERC emphasized that maintaining diversity across electric generation and consumption will help ensure system reliability and resilience. NERC also noted the complexity of load balancing and forecasting associated with the changing resource mix, as load and demand will continue to increase in parallel to bringing more data centers onto the grid.

NERC's statement discussed several potential reliability improvements associated with co-located large loads. Proximity between large loads and power generation sources can reduce energy loss while improving transmission reliability. This co-location fosters improved coordination, leading to better load management and reduced strain on the BPS. Grid stability may also be enhanced if the proximity creates flexibility to adjust demand during critical conditions. NERC noted that nuclear power is a particularly advantageous resource for co-located large loads due to its inherent high-capacity factor, load-carrying ability, and steady performance even in extreme weather conditions.

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[15] *See* FERC Docket No. AD24-11-000.

[16] N. Am. Elec. Reliability Corp., *Statement of Howard Gugel*, Docket No. AD24-11-000 (submitted Nov. 1, 2024).

In addition to the benefits of co-located large loads, NERC highlighted several potential risks related to performance requirements which it reiterates in this proceeding. As the Commission noted in its Show Cause Order, system operators may lack sufficient information to perform reliability analysis on co-located large loads.[17] A key risk is that large loads may or may not be visible to system operators depending on the load's operation and interconnection type. As stated above, NERC reiterates the importance of this consideration. If a load is connected but operating conditions are providing only partial or no generation, there is a risk of thermal overloads and voltage or stability issues. Fluctuations from large loads during faults or switching can cause issues with voltage support, frequency response, stability, and protection system coordination. NERC also noted that the significant power consumption associated with artificial intelligence operations requires evaluation for impact to grid operations. System restoration concerns also present risks, particularly if the grid requires restoration efforts before the generation source can serve the co-located loads. The nature of co-located large loads also gives rise to cybersecurity risks, including a single point of failure or cascading failures on either the generation or load side unless systems and assets are segmented to prevent shared access. Finally, the absence of transient stability load models in the interconnection process is a currently identified gap that NERC recommends should be addressed.

c. Incident Review Report – Considerations for Simultaneous Voltage-Sensitive Load Reductions

In January 2025, NERC released an incident report on a recent large loads loss event in the Eastern Interconnection (**Attachment B**).[18] The report highlighted the potential risks and challenges of rapid connection to or disconnection from the grid, particularly for voltage-sensitive

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[17] Show Cause Order at P 83.

[18] NERC, Incident Review: Considering Simultaneous Voltage-Sensitive Load Reductions (Jan. 8, 2025), https://www.nerc.com/pa/rrm/ea/Documents/Incident_Review_Large_Load_Loss.pdf.

large loads loss at data centers or cryptocurrency mining facilities. Removal of large loads typically causes both frequency and voltage to rise, due to the imbalance between load and generation and due to reduced power flowing through the system.

The incident reviewed involved a 230 kV transmission line fault, which caused a data center customer to remove approximately 1,500 MW of voltage-sensitive load from the grid. In this situation, the frequency and voltage rose, but not to a level causing significant risk to the reliability of the grid. Operators did, however, take action to reduce the voltage to normal operating levels. In reviewing the incident, NERC held discussions with the data center owners to understand why the load loss occurred during the brief fault on the grid. NERC learned that data centers are sensitive to voltage disturbances, and design protections and controls to manage equipment outages related to such disturbances. Data centers employ uninterruptible power supply (UPS) systems to ride-through voltage disturbances while protecting critical computer and cooling equipment. When a disturbance occurs, these UPS systems take over power supply for the data centers. The loads typically need to be manually reconnected to the grid to bring the load back online, as happened in this case. While there were no significant issues with reconnection in this case, it exemplifies the type of load loss that can occur with little or no notice to system operators.

This incident demonstrates that there are several potential reliability risks associated with similarly large, voltage-sensitive loads. The voltage ride-through characteristics and dynamic nature of large loads presents challenges to Balancing Authorities (BA) and Transmission Operators (TOP). While the incident described here did not result in any significant reconnection issues, load reconnection needs to be performed in a controlled manner in coordination with the BA and TOP. The size of large loads makes ramp rates for these users of the BPS as critical as ramp rates for generation resources. In addition, large loads require careful management of voltage and load/generation balance during reconnection. The incident report describes several actions and potential questions for TOPs and Transmission Owners (TO) to consider going forward to prevent significant issues related to large load disconnection or reconnection. This incident report demonstrates the challenges with integration even when large loss does not significantly affect grid operations.

d. NERC Board of Trustees Panel and Action Plan to Address Challenges of Large Load Integration

The NERC Board has also engaged stakeholders to discuss the potential impacts of large loads integration. In February 2025, the Board held a panel discussion addressing risks related to integrating large loads.[19] The Board recognized that large loads are increasingly connecting to the grid, and emphasized that integration must support reliable BPS operations rather than reduce performance.

In preparation, the Board solicited input from NERC's Member Representatives Committee (the "MRC").[20] Specifically, the Board sought information on potential NERC actions related to the risks to reliability, resilience, and security of the grid as large loads are increasingly brought online.[21] The Board received input from industry representatives and stakeholders that supported a continued strong focus on reliability and stakeholder engagement. During the panel discussion, panelists discussed how to integrate large loads onto the grid in a manner that supports reliable operation of the BPS without reducing grid performance. Panelists also discussed how to

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19 *See* NERC Quarterly Technical Session, Agenda Item 2: Technical Panel Session on Large Load Integration (Feb. 12, 2025), https://www.nerc.com/gov/bot/QuarterlyTechnicalSessions/Technical Session Agenda Package February 12, 2025.pdf.

20 The Member Representatives Committee (MRC) elects independent trustees, votes on amendments to the Bylaws, and provides advice and recommendations to the Board with respect to the development of annual budgets, business plans and funding mechanisms, and other matters pertinent to the purpose and operations of the corporation. *See* https://www.nerc.com/gov/bot/MRC/Pages/default.aspx.

21 *See* Letter from NERC Board to Member Representatives Committee (Jan. 9, 2025), https://www.nerc.com/gov/bot/Agenda highlights and Mintues 2013/Q1-Input-Letter-Package-February-2025-PUBLIC-POSTING.pdf

better understand large load behavior relative to varying system conditions. Overall, there was substantial support for the work of the Task Force, and interest in identifying gaps in Reliability Standards, developing scenarios for incorporating large loads, increasing industry collaboration, and providing regular updates to industry on task progress.

In response to the input and discussions, the NERC Board approved a resolution directing NERC to develop an action plan identifying and addressing the risks associated with large loads on the BPS.[22] The action plan will be due at the Board's May 2025 meeting. This action by the Board acknowledged the challenges presented by large commercial and industrial loads interconnecting with the BPS, and the growing need for NERC and industry to better understand these systems and the impacts presented by increasing integration and demand.

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22 NERC Bd. of Trustees, Draft Minutes (Feb. 13, 2025) at pp. 12-13, https://www.nerc.com/gov/bot/Agenda highlights and Mintues 2013/DRAFT Minutes - Board of Trustees Open -February 13, 2025.pdf.

III. CONCLUSION

WHEREFORE, for the reasons stated above, NERC respectfully requests that the Commission accept the comments herein.

Respectfully submitted,

/s/ *Caelyn Palmer*
Candice Castaneda
Senior Counsel
Caelyn Palmer
Counsel
North American Electric Reliability Corporation
1401 H Street, N.W., Suite 410
Washington, D.C. 20005
(202) 400-3000
(202) 644-8099 – facsimile
candice.castaneda@nerc.net
caelyn.palmer@nerc.net
Counsel for the North American Electric Reliability Corporation

Date: April 23, 2025

CERTIFICATE OF SERVICE

I hereby certify that I have served a copy of the foregoing document upon all parties listed on the official service list compiled by the Secretary in this proceeding. Dated at Washington, D.C. this 23rd day of April, 2025.

/s/ *Caelyn Palmer*
Caelyn Palmer
Counsel for the North American Electric Reliability Corporation

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Attachment A

NERC Activities and Plans to Address
Reliability Impacts from Large Load Integration

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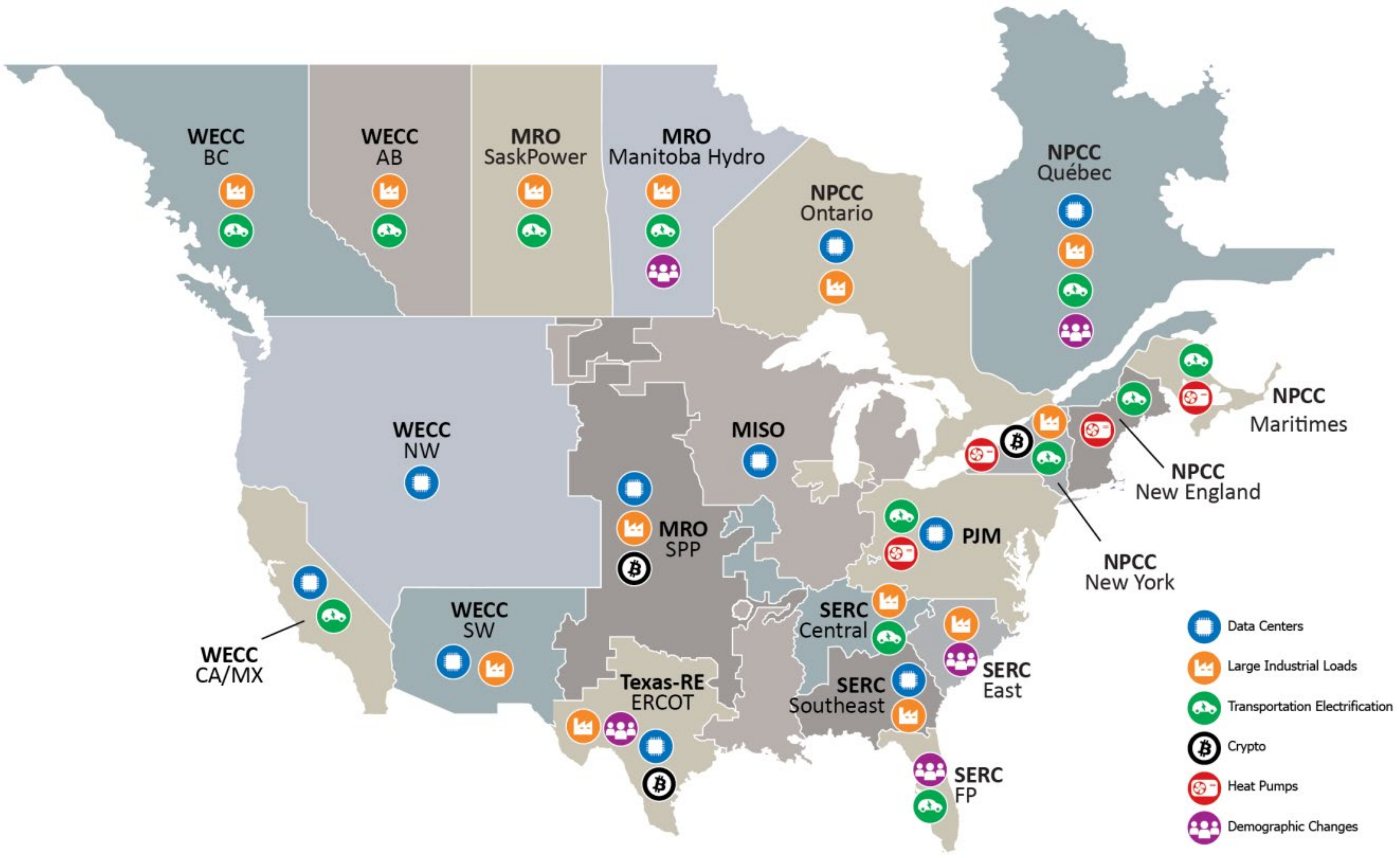
NERC Activities and Plans to Address Reliability Impacts from Large Load Integration

Mark Lauby, Senior Vice President and Chief Engineer
FERC Open Meeting
April 17, 2025

Primary Demand Drivers by Assessment Area



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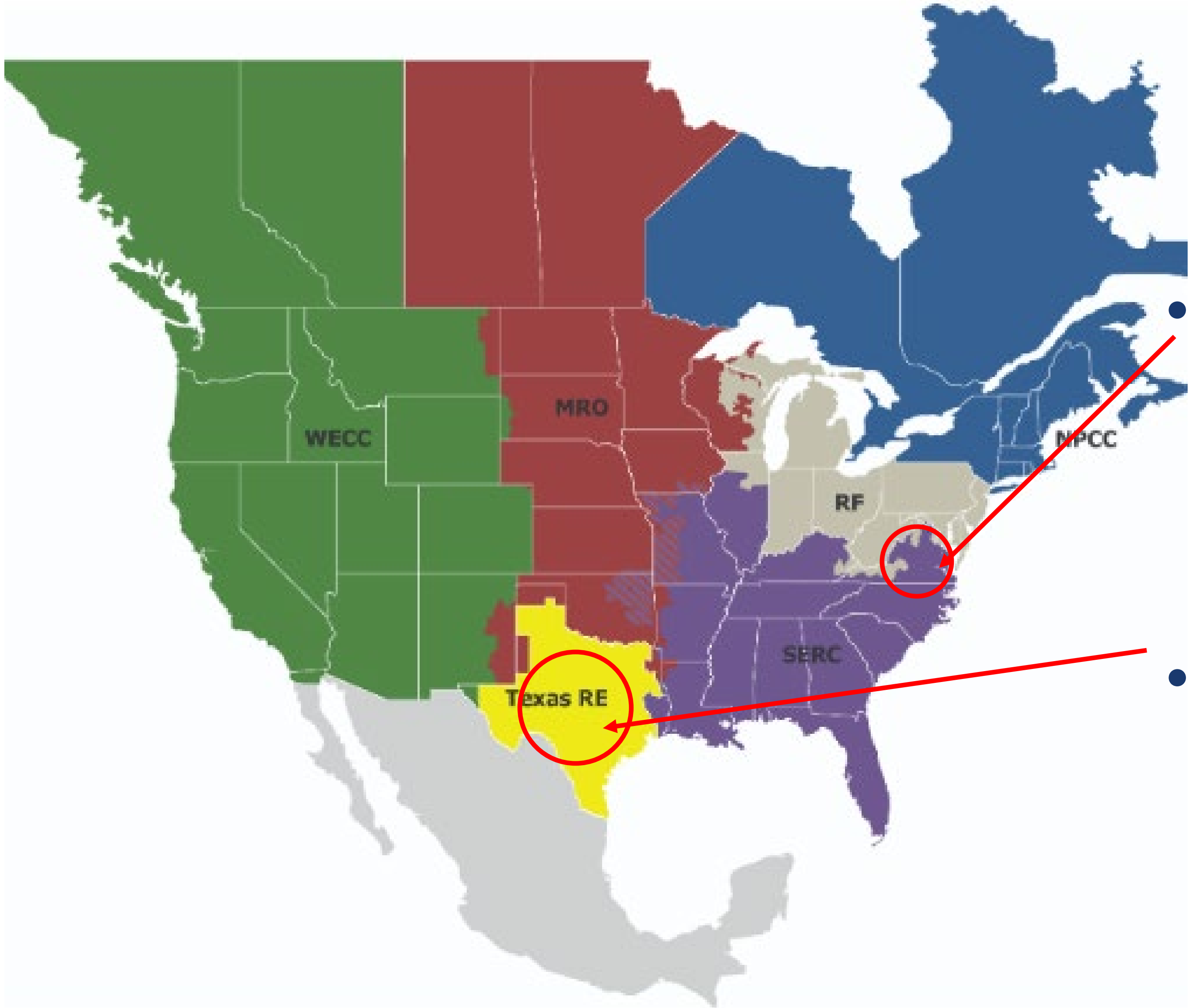
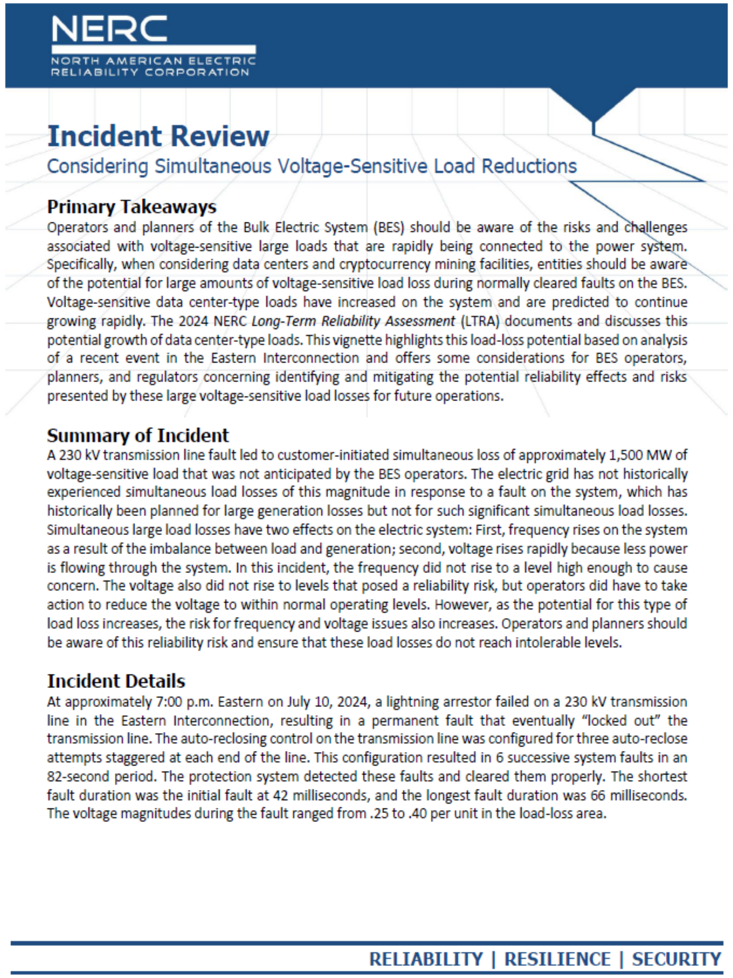
Voltage Sensitive Load Loss Events



- EI Data Center Load Loss Events
  - Impacts the state of Virginia
    - July 2024 – 1,500 MW Load Loss in Loudoun County
    - February 2025 – 1,800 MW Load Loss in Loudoun & Fairfax Counties
- ERCOT Crypto-Mining Load Loss
  - 25 Load Loss Events (Nov 2023 – Jan 2025)
  - 100MW – 400MW Load loss

Data Center Load Loss Event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Incident Review

Considering Simultaneous Voltage-Sensitive Load Reductions

Primary Takeaways

Operators and planners of the Bulk Electric System (BES) should be aware of the risks and challenges associated with voltage-sensitive large loads that are rapidly being connected to the power system. Specifically, when considering data centers and cryptocurrency mining facilities, entities should be aware of the potential for large amounts of voltage-sensitive load loss during normally cleared faults on the BES. Voltage-sensitive data center-type loads have increased on the system and are predicted to continue growing rapidly. The 2024 NERC *Long-Term Reliability Assessment* (LTRA) documents and discusses this potential growth of data center-type loads. This vignette highlights this load-loss potential based on analysis of a recent event in the Eastern Interconnection and offers some considerations for BES operators, planners, and regulators concerning identifying and mitigating the potential reliability effects and risks presented by these large voltage-sensitive load losses for future operations.

Summary of Incident

A 230 kV transmission line fault led to customer-initiated simultaneous loss of approximately 1,500 MW of voltage-sensitive load that was not anticipated by the BES operators. The electric grid has not historically experienced simultaneous load losses of this magnitude in response to a fault on the system, which has historically been planned for large generation losses but not for such significant simultaneous load losses. Simultaneous large load losses have two effects on the electric system: First, frequency rises on the system as a result of the imbalance between load and generation; second, voltage rises rapidly because less power is flowing through the system. In this incident, the frequency did not rise to a level high enough to cause concern. The voltage also did not rise to levels that posed a reliability risk, but operators did have to take action to reduce the voltage to within normal operating levels. However, as the potential for this type of load loss increases, the risk for frequency and voltage issues also increases. Operators and planners should be aware of this reliability risk and ensure that these load losses do not reach intolerable levels.

Incident Details

At approximately 7:00 p.m. Eastern on July 10, 2024, a lightning arrestor failed on a 230 kV transmission line in the Eastern Interconnection, resulting in a permanent fault that eventually "locked out" the transmission line. The auto-reclosing control on the transmission line was configured for three auto-reclose attempts staggered at each end of the line. This configuration resulted in 6 successive system faults in an 82-second period. The protection system detected these faults and cleared them properly. The shortest fault duration was the initial fault at 42 milliseconds, and the longest fault duration was 66 milliseconds. The voltage magnitudes during the fault ranged from .25 to .40 per unit in the load-loss area.

RELIABILITY | RESILIENCE | SECURITY

Event:

- 1,500MW load loss, exclusively data center load
- Coincident with 230kV normal line fault clearing
- Widespread: 60 different load points, 25 substations

Conclusions:

- Require models for large loads to enable studies to determine risk to BES for coincident large load losses
- Determine if large loads should be a NERC Registered Entity
- Need for new or modifications to Standards

Large Load Task Force Framework to Address Reliability and Security Risks

Risk Identification

Validation

Prioritization

White Paper (Q2):
Characteristics and Risks
of Emerging Large Loads

Gap Analysis

White Paper (Q3):
Assessment of Gaps in Existing Practices, Requirements, and Reliability Standards for Emerging Large Loads

Risk Mitigation

Reliability Guideline (Q1 2026):
Risk Mitigation for Emerging Large Loads

Standard Authorization Request(s):
Updates to Reliability Standards will likely be needed

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Draft LLTF First White Paper: Prioritization of Risks

High	Medium	Low

• **Long-Term Planning**
  ◦ Resource Adequacy
• **Operations/Balancing**
  ◦ Balancing and Reserves
• **Stability**
  ◦ Dynamic Modeling
  ◦ Ride-through
  ◦ Frequency Stability
  ◦ Voltage Stability
  ◦ Oscillations
• **Resilience**
  ◦ Automatic UFLS Programs
	• **Long-Term Planning**
	  ◦ Demand Forecasting
	  ◦ Transmission Adequacy
	• **Operations/Balancing**
	  ◦ Short-Term Demand Forecasting
	  ◦ Lack of Real-Time Coordination
	• **Resilience**
	  ◦ Load-Shed Obligation Impacts
		• **Power Quality**
		  ◦ Harmonics
		  ◦ Voltage Fluctuations
		• **Security Risks**
		  ◦ Cyber Security
		• **Resilience**
		  ◦ System Restoration

Draft LLTF First White Paper: Characteristics and Risks of Emerging Large Loads

Recommendations for Large Load Task Force (#1-#3)

- Standard Gap Identification
- Risk Mitigation
- Characteristic Definition & Categorization

Recommendations for Reliability Security Technical Committee (RSTC) Working Groups (#4-#6)

- Model Development and refinement for Large Loads
- Develop approaches to differentiate computation facilities
- Assess possible protection system impacts

Recommendation to Utilities (#7)

- Industry must collect data that to understand the unique risks associated with connecting a large load

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NERC Draft Action Plan: Large Loads

Task Description	Target
Reliability Security Technical Committee's Large Load Task Force (LLTF)	Through Q2 – 2026
NERC-led Collaborative Industry Sessions	Through Q4 – 2025
Registration Analysis • *Legal basis for registration of large users of the bulk power system* • *Consider if Load Serving Entities (LSE) accountable for large load performance* • *Ability to write Reliability Standards Large Loads or LSEs would follow*	Through Q4 – 2025
Complementary Activities • *Load Modeling Working Group* • *Coordination with EPRI, ESIG, and large load industry groups* • *Industry Communications and outreach* • *Continued Incident Analysis and Lessons Learned*	Through Q4 – 2025

Questions and Answers

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Attachment B

NERC Incident Review:
Considering Simultaneous Voltage-Sensitive Load Reductions

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Incident Review

Considering Simultaneous Voltage-Sensitive Load Reductions

Primary Takeaways

Operators and planners of the Bulk Electric System (BES) should be aware of the risks and challenges associated with voltage-sensitive large loads that are rapidly being connected to the power system. Specifically, when considering data centers and cryptocurrency mining facilities, entities should be aware of the potential for large amounts of voltage-sensitive load loss during normally cleared faults on the BES. Voltage-sensitive data center-type loads have increased on the system and are predicted to continue growing rapidly. The 2024 NERC *Long-Term Reliability Assessment* (LTRA) documents and discusses this potential growth of data center-type loads. This vignette highlights this load-loss potential based on analysis of a recent event in the Eastern Interconnection and offers some considerations for BES operators, planners, and regulators concerning identifying and mitigating the potential reliability effects and risks presented by these large voltage-sensitive load losses for future operations.

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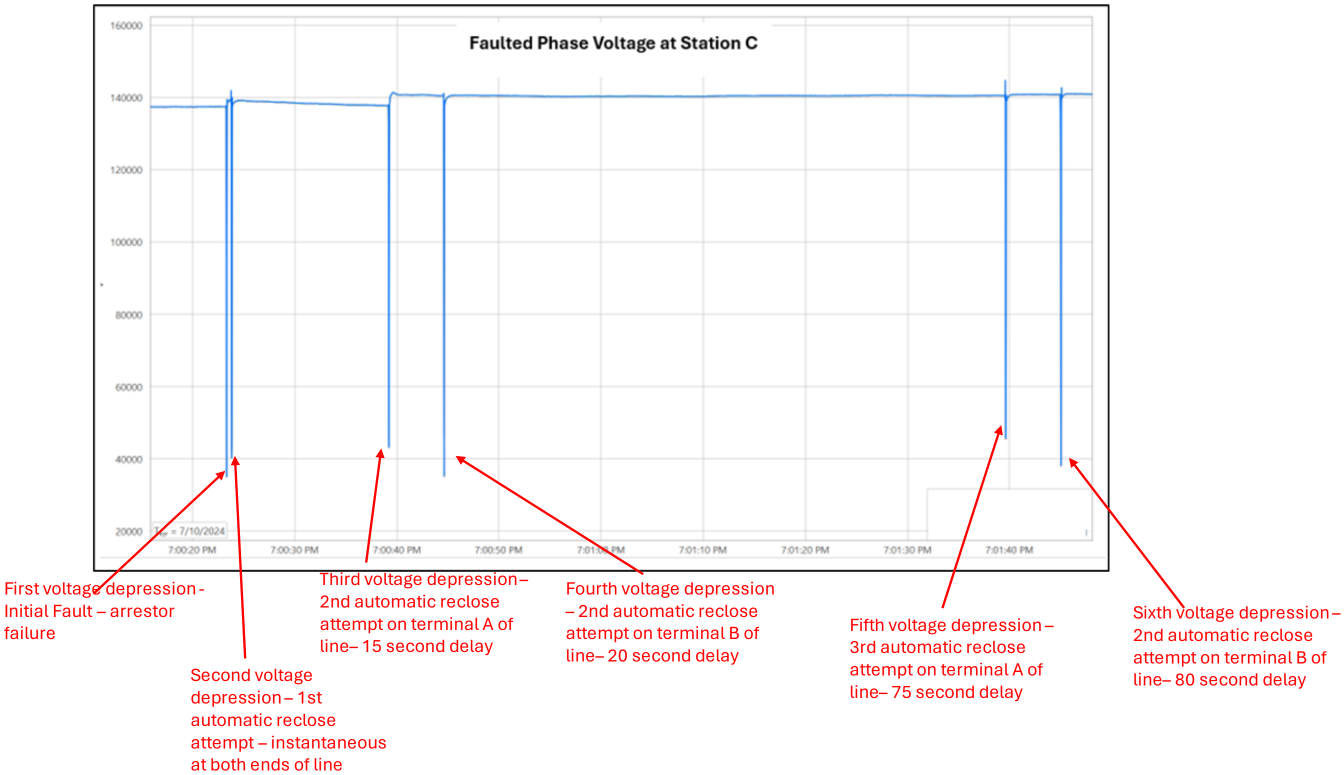

Figure 1: Faulted Phase Voltage

Table 1: Voltage Depression Times and Durations			
		Voltage Depression Time (hh:mm:ss.msec)	**Voltage Depression Duration (milliseconds)**
Voltage Depression 1	Initial Fault (arrestor failure)	19:00:23.351	42
Voltage Depression 2	Instantaneous and simultaneous automatic reclose at both terminals	19:00:23.883	66
Voltage Depression 3	2nd Automatic reclose at terminal A	19:00:39.211	58
Voltage Depression 4	2nd automatic reclose at terminal B	19:00:44.630	50
Voltage Depression 5	3rd automatic reclose at terminal A	19:01:39.600	66
Voltage Depression 6	3rd automatic reclose at terminal B	19:01:45.016	59

Coincident with this six-fault disturbance, the same local area saw an approximate 1,500 MW of load reduction. None of this load was disconnected from the system by utility equipment; rather, the load was disconnected on the customer side by customer protection and controls. It was determined that the 1,500

MW of load reduction was exclusively data center-type load. The area where the disturbance occurred has a high concentration of data center loads.

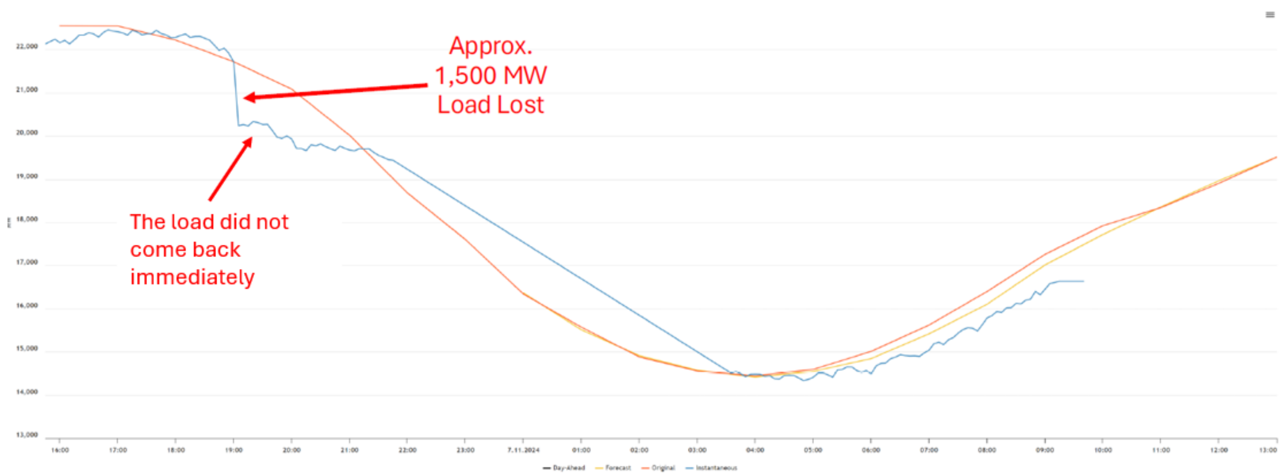

Figure 2: System Load Chart

Frequency and voltage rose due to the load loss. Frequency rose to a high of 60.047 Hz and settled back to 60.0 Hz in approximately 4 minutes. At the highest level, voltage rose to 1.07 per unit. Operators removed shunt capacitor banks in the local area to return voltages to normal operating values.

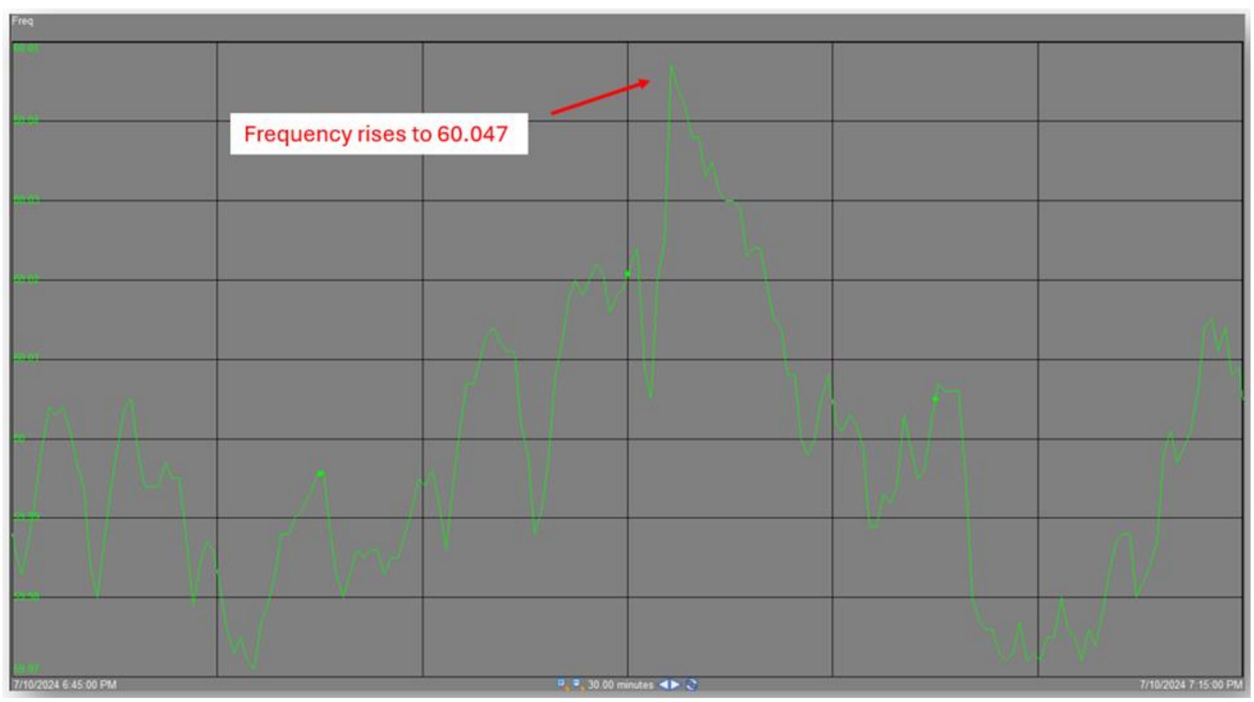

Figure 3: Frequency at Time of Load Loss

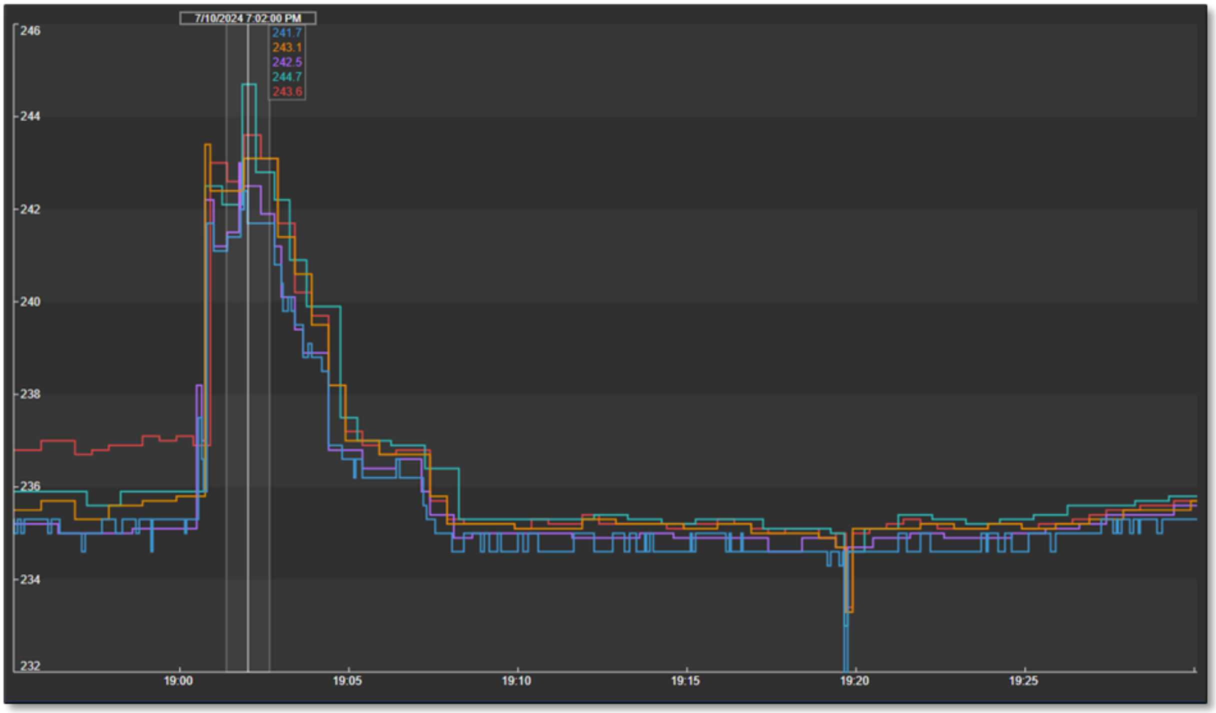

Figure 4: 230 kV Voltages

Load Details

Discussions were held with data center owners to understand the specific cause of their load reductions. It was determined that the data centers transferred their loads to their backup power systems in response to the disturbance. Data center loads are sensitive to voltage disturbances. The data center protections and controls are designed to avoid equipment outages for voltage disturbances. In addition to the computer equipment at these facilities, cooling equipment is also critical to the operation of the data center and sensitive to voltage disturbances. To ride through voltage disturbances on the electric grid, data centers employ uninterruptible power supply (UPS) systems that will instantaneously take over providing power to the data center equipment when a grid disturbance occurs. The differing types and designs of these UPS systems cause differences in the characteristics of the data center responses to a voltage disturbance. A centralized design uses UPS systems at the load-center level that are typically in the range of 2–5 MWs. The UPS uses power electronics to switch the load to a battery bank connected to the UPS. These battery banks are not designed to supply the load for long periods of time but rather to power the load for the short time periods of disturbances or—in the case of a complete electric grid outage—long enough to start a backup generator that will then provide power to the UPS. The decentralized UPS design uses many smaller UPSs at the rack level. These rack-mounted UPSs are typically in the range of 3–4 kW. The decentralized UPS systems operate similarly to the centralized UPS systems, just on a smaller scale. Another type of UPS is a dynamic/diesel rotary uninterruptible power supply (DRUPS). These systems use a flywheel to provide uninterruptible power and a clutch system to quickly start and connect a diesel engine upon a disturbance on the electric grid.

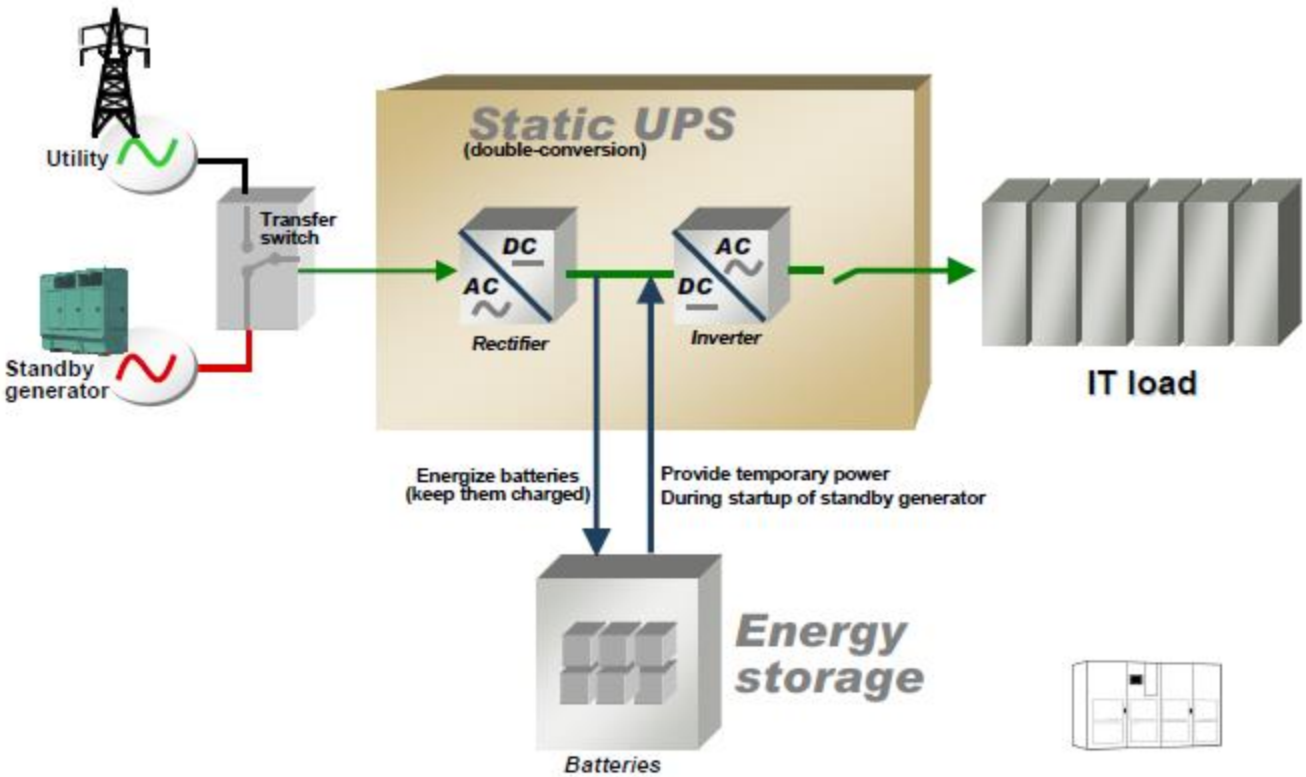

Figure 5: Static Centralized UPS
[Source: Schneider Electric White Paper 92]

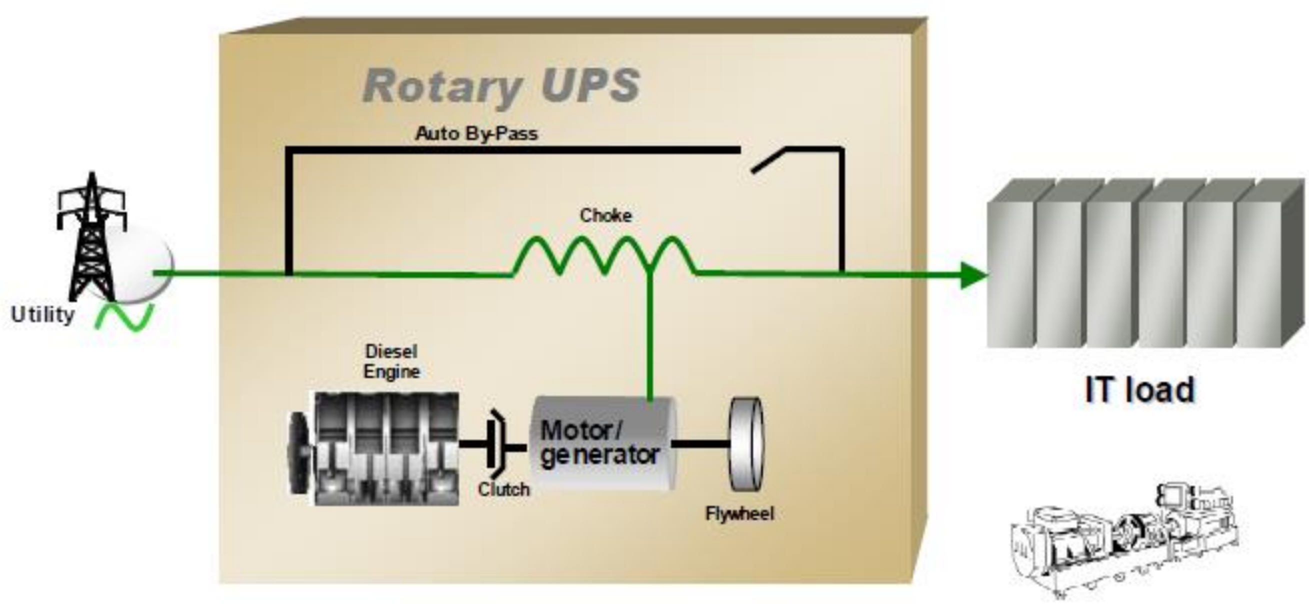

Figure 6: DRUPS
[Source: Schneider Electric White Paper 92]

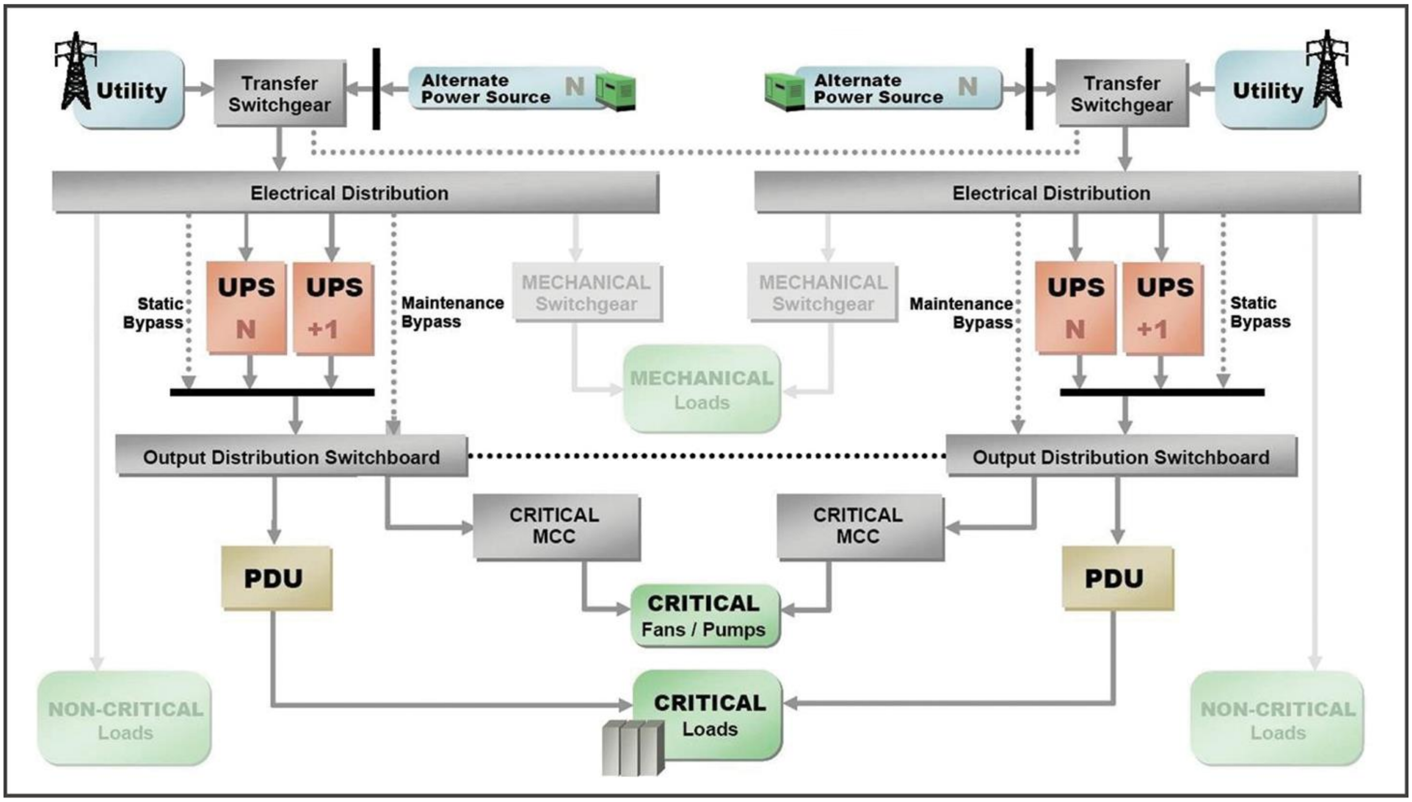

Figure 7: Typical Centralized UPS Power Distribution
[Source: Uptime Institute Journal]

The load characteristics of these types of UPS systems differ in response to a transient disturbance on the electric grid. For the static centralized and decentralized UPS systems that utilize batteries, the load will be taken over by the battery when the transient voltage disturbance occurs. Since it is a transient disturbance, such as a temporary fault on the electric grid, the grid voltage will typically return to normal in milliseconds. Once the grid voltage returns to normal, the load will then be transferred back to the grid. A typical load characteristic for these types of static UPS systems, as seen by the grid, is shown in **Figure 8**. Upon detecting the transient voltage disturbance, the DRUPS system will immediately transfer the load to the flywheel/ac generator and start the engine that will act as the prime mover for the generator before the flywheel exhausts its kinetic energy. This system will not quickly transfer the load back to the grid after the transient disturbance has cleared and the grid voltage returns to normal. Typically, transferring the load back to the grid from the DRUPS system must be done manually. A typical load characteristic for a DRUPS system, as seen by the grid, is shown in **Figure 9**. As can be seen in these figures, the typical static UPS system load characteristic, as seen by the grid, is a short-duration loss of load that returns quickly after the transient disturbance clears. The typical DRUPS system load characteristic, as seen by the grid, is a loss of load that does not return quickly after the transient disturbance clears.

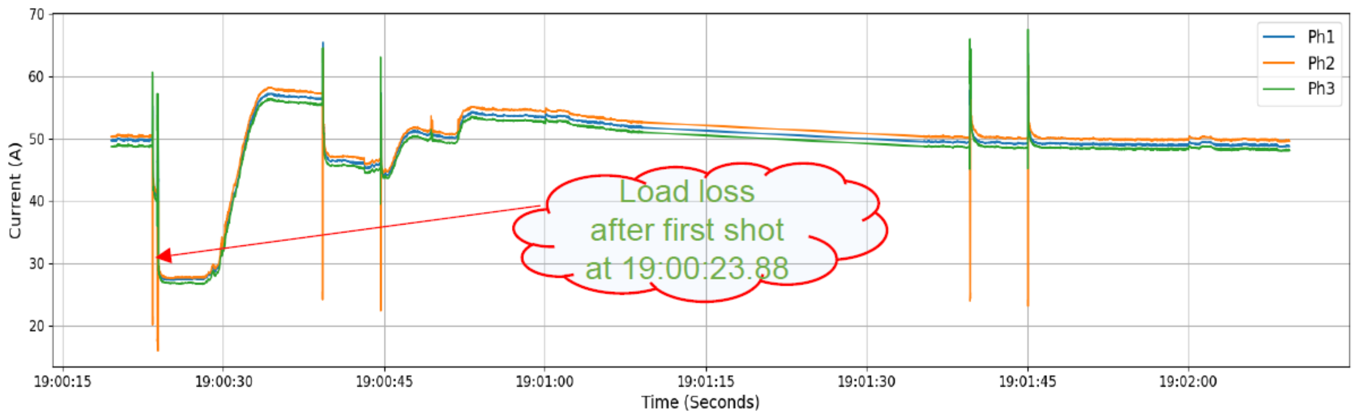

Figure 8: Static UPS Load Characteristic

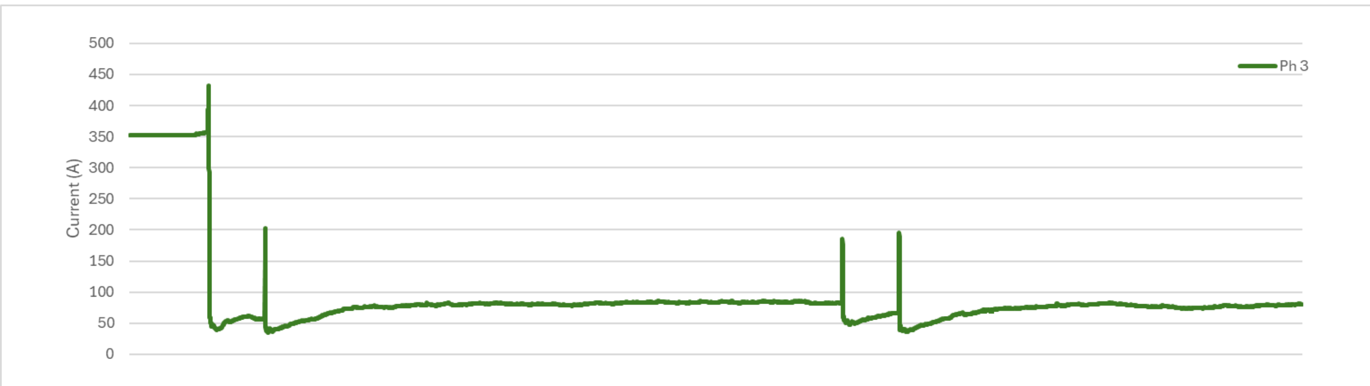

Figure 9: DRUPS Load Characteristic

Discussions with the data center owners also identified another protection/control scheme that impacts the response of data center load to voltage disturbances on the grid. The scheme detects and counts voltage disturbances on the grid. If a certain number of voltage disturbances are seen within a certain time, the data center will transfer its load to the backup system, and it will remain there until it is manually reconnected to the grid. The typical number of voltage disturbances that trigger this scheme is three, and a typical time is one minute. As such, three voltage disturbances within one minute will result in data centers using this protection/control scheme transferring their load off the grid and staying off until they manually transfer back. This scheme can be deployed on both centralized and decentralized UPS designs. A load characteristic for this type of data center control scheme can be seen in **Figure 10**.

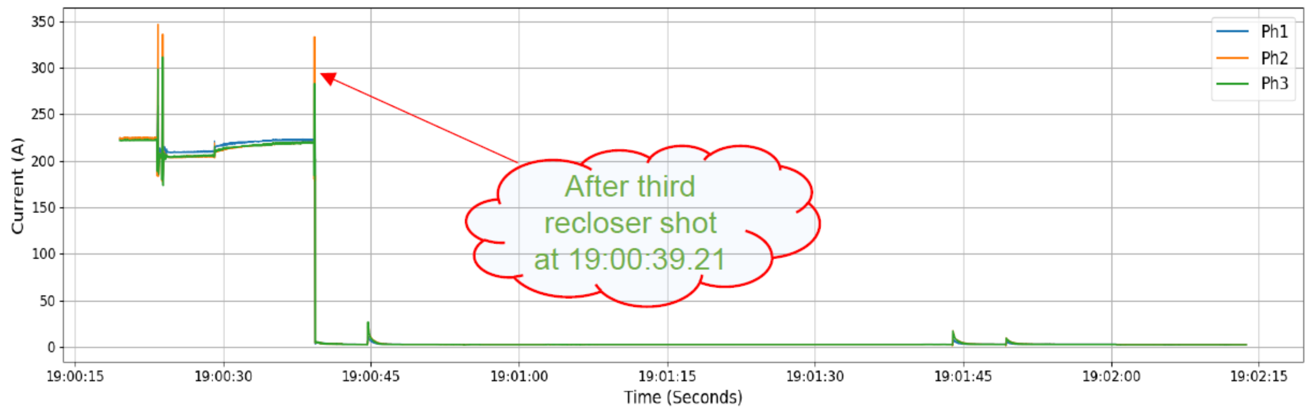

Figure 10: Voltage Disturbance Counting Scheme Load Characteristic

While these three load characteristics were predominant in this event, many load characteristic variations exist. These characteristics are determined by the numerous vendor-supplied equipment controls within the data center, including the vendor-specific UPS controls. Additionally, controls under the purview of data center owner/operators, such as a certain number of disturbances within a certain period of time, also determine the characteristic response to system disturbances.

Most of the sustained load reduction occurred simultaneously with the third voltage depression, which coincided with the third automatic reclosing attempt. At that time, approximately 1,260 MW of load dropped off the electric grid and did not return for hours. Most of the load loss in this event can be attributed to the interaction between the automatic reclosing sequence on the faulted transmission line and the data center's protection/control scheme that counts the number of voltage disturbances within a specified period of time.

While this incident did not present any significant issues with the reconnection of the large loads, the potential exists for issues in future incidents if the load is not reconnected in a controlled manner. Significant amounts of load being reconnected to the system present challenges to Balancing Authorities (BA) and Transmission Operators (TOP). Ramp rates for load connection are just as critical to system operations as generation ramping. Voltage management and maintaining balance between load and generation are considerations that need to be given for load reconnection ramp rates.

This incident has highlighted potential reliability risks to the BES with respect to the voltage ride-through characteristics of large data center loads. Similar incidents have occurred in other Interconnections with cryptocurrency mining loads as well as oil/gas loads. While these loads are different than the data center loads in this incident, they present the same challenges to the operators and planners of the BES. Understanding the changing dynamic nature of load is critical to the future operation of the BES.

Future Considerations

While this disturbance did not cause significant operating issues with the grid at this location and at this time, as data center loads continue to grow rapidly, the risk could quickly increase. Actions that TOPs and Transmission Planners (TP) should start taking to avoid significant issues in the future are listed below:

- Require dynamic response models of large loads in their facility interconnection requirements

- Perform studies to determine the potential magnitude of load loss for system disturbances (faults)
  - Study the impact that these large load losses would have on the system
- Take into consideration the potential for voltage-sensitive load loss when configuring automatic reclosing schemes
- Actively monitor to detect load losses coincident with system faults
- TOPs: Ensure that operating agreements with large loads include ramp rates when connecting/reconnecting large loads to the system
- Critical questions that must be resolved:
  - Should large loads be a NERC registered entity?
  - Should NERC Reliability Standard modifications be developed for large load interconnection requirements?
  - What studies should TOPs perform to "consider" the impacts of large load operation?
  - What is the definition of a large load?

Transmission Owners (TO), TOPs, TPs, and large-load owners will have to work collaboratively to identify and mitigate reliability risks posed by large load losses during system faults. The NERC Large Load Task Force (LLTF) is one group where this type of collaboration can take place.

For more information, please contact:
NERC – Event Analysis

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