ESIG
Large Loads
Task Force

# Interconnection Processes for Large Loads

## CURRENT PRACTICES AND RECOMMENDATIONS

A Report by the
Energy Systems Integration Group's
Large Loads Task Force

June 2026

ESIG
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# Interconnection Processes for Large Loads: Current Practices and Recommendations

**A Report by the Energy Systems Integration Group's Large Loads Task Force**


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## Disclaimer

This report was produced by a project team made up of diverse members with diverse viewpoints and levels of participation. Specific statements may not necessarily represent a consensus among all participants or the views of participants' employers.


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## Preface to ESIG Large Loads Task Force Reports

This report is one of 11 reports by the ESIG Large Loads Task Force, which was formed to assist the power industry in addressing new challenges introduced by the rapid proliferation of large electronic loads such as data centers, as well as other large loads including manufacturing, electric vehicle fleets, and hydrogen production. The titles of the reports are as follows:

- Grid Integration of Large Loads: Introduction to the Large Loads Task Force, Data Needs, and Flexibility
- Forecasting for Large Loads: Current Practices and Recommendations
- Interconnection Processes for Large Loads: Current Practices and Recommendations
- Large Load Performance Requirements: Current Practices and Recommendations
- Large Loads: Behaviors, Capabilities, and Limitations
- Reliability Impacts of Large, Power Electronics–Interfaced Loads
- Large Load Disturbance Events
- Large Load Modeling for Dynamic Studies: Current Practices and Recommendations
- Transmission Planning with Large Loads: Current Practices and Recommendations
- Resource Adequacy with Large Loads: Planning for Flexibility to Accelerate Integration
- Wholesale Market Design and Operations for Systems with Large Loads: Current Practices and Recommendations

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# Abbreviations

| | |
|---|---|
| AI | Artificial intelligence |
| ANOPR | Advance Notice of Proposed Rulemaking |
| BYOG | Bring your own generation |
| CAISO | California Independent System Operator |
| DCC | Demand Connection Code |
| DER | Distributed energy resource |
| EMT | Electromagnetic transient |
| ERCOT | Electric Reliability Council of Texas |
| FERC | Federal Energy Regulatory Commission |
| HILL | High-Impact Large Load |
| HILLGA | High-Impact Large Load Generator Assessment |
| IBR | Inverter-based resource |
| ISO | Independent system operator |
| LGIA | Large Generator Interconnection Agreement |
| LGIP | Large Generator Interconnection Procedures |
| LLIA | Large Load Interconnection Agreement |
| LLIP | Large Load Interconnection Procedure |
| MISO | Midcontinent Independent System Operator |
| NERC | North American Electric Reliability Corporation |
| NYISO | New York Independent System Operator |
| PSPD | Postive-sequence phasor-domain |
| RTO | Regional transmission organization |
| SPP | Southwest Power Pool |
| UPS | Uninterruptible power supply |
| U.S. DOE | U.S. Department of Energy |

# Executive Summary

The interconnection of large loads into the U.S. electric power system has accelerated sharply in recent years, driven primarily by the rapid proliferation of data centers and other high-demand facilities. Interconnection requests for these loads have grown exponentially in both number and magnitude, reshaping load growth forecasts across virtually every region of the country and placing new and unanticipated pressures across the electricity system. The interconnection process, encompassing the technical studies, legal agreements, and procedural requirements necessary to connect new electrical facilities to the grid while preserving system reliability, will need to expand to serve large loads' needs and fully capture their impacts on the grid.

The pressures inherent in the exponential growth of large load interconnection requests manifest in several interrelated challenges. These include reliability risks, concerns about cost allocation, and disputes between large load customers and grid owners and operators over rights, obligations, and timelines. At the bulk power system level, large load facilities introduce novel reliability risks stemming from their very large power demand, power electronic interfaces, and varying power demand dictated by computational processes' intensity, including artificial intelligence training and inference (application) workloads. Financially, the speculative nature of some large load interconnection requests raises legitimate concerns about cost allocation: infrastructure investments triggered by interconnection requests may ultimately be underutilized if large load projects do not advance to commercial operation. These dynamics also have implications for utility customer rates, wholesale market rates, and long-term system planning.

**The interconnection process, encompassing the technical studies, legal agreements, and procedural requirements necessary to connect new electrical facilities to the grid while preserving system reliability, will need to expand to serve large loads' needs and fully capture their impacts on the grid.**

Underpinning all of these challenges is the question of which regulatory authorities have jurisdiction over each aspect of large load interconnection. While generator interconnection is regulated by the Federal Energy Regulatory Commission (FERC) and state public utility commissions, regulatory authority over large load interconnection standards and procedures is less clear. Currently, FERC oversees generator interconnection "for the purpose of making sales of electric energy for resale in interstate commerce" (that is, when the generator plans to sell electricity at wholesale into interstate markets not directly to an end-use customer) (FERC, 2023a, 804). For regulated utilities, state public utility commissions oversee generator interconnection that does not involve sales for resale. The North American Electric Reliability Corporation (NERC), through a stakeholder-driven standards process, sets reliability standards for generation. The development of these standards can be mandated by FERC (e.g., FERC Order 901) or proposed by industry stakeholders (including NERC) based on reliability needs. Furthermore, the new Category 2 inverter-based resources, defined as those "that either have or contribute to an aggregate nameplate capacity of greater than or equal to 20 MVA" (NERC, 2026d), face 11 applicable NERC reliability standards as of March 2026. However, there is no similar process today for reliability standards for large loads.

Historically, the lack of clarity around regulatory authority over large load interconnection standards and procedures did not lead to significant issues because load growth was incremental and more evenly geographically distributed; however, reliability challenges command much more attention in an era when individual loads may approach or exceed the scale of conventional generating units and connect at all voltage levels of the grid on the distribution system, sub-transmission level, and transmission system. At the time of this writing, load facilities are not required to register with NERC; since they are not NERC-registered entities, they do not have any applicable NERC reliability standards, even as a 1 GW data center can impact the bulk power system far more than, for example, a 20 MW wind plant. NERC is working to rapidly develop registration criteria and reliability standards for large loads in 2026 through its large load action plan (NERC, 2026e).

At the regional level, existing large load interconnection processes are not sufficient to maintain bulk power system reliability with the increase in interconnection requests and the growing set of risks to the system.

Historically, utilities managed all load interconnections directly, regardless of size. As demand from large loads grows and the reliability risks become greater, additional coordination is needed in the large load interconnection process to ensure that all assumptions, data, models, and reliability solutions are shared and managed consistently. This includes coordination between independent system operators (ISOs) and regional transmission organizations (RTOs) and utilities.

The Energy Systems Integration Group's (ESIG's) Large Loads Task Force examined the large load interconnection process in detail, mapped current practices across select utilities and ISO/RTO regions where large load interconnection practices are evolving more rapidly, and identified the gaps, bottlenecks, and systemic risks. This report outlines the challenges and deficiencies and offers recommendations to make the process more harmonized, efficient, and transparent. The recommendations address the unique operational and technical characteristics of new large loads while allowing for local and regional differences.

## Key Issues in the Large Load Interconnection Process

The large load interconnection process is the starting point for determining which projects will be able to interconnect to the grid, and when. Understanding this process is essential to any substantive discussion of large load deployment. The interconnection process for large loads needs to address an unusually broad range of issues, including these elements and fundamental questions.

### Significant Variation in Large Load Interconnection Processes and Use of Processes Not Designed for Today's Complex Facilities

Load interconnection processes vary significantly across transmission utilities and regions, with many jurisdictions relying on ad hoc procedures that were not designed for facilities of the scale or complexity of today's large loads. In addition, flexible interconnection options, including non-firm, surplus, and provisional service offerings, are not uniformly available or well understood across the industry.

Large load facilities' increasingly common pairing with on-site generation puts additional strain on the generator interconnection process, requiring reconsideration of how to study and treat interconnecting generators when they are operationally coupled with large loads. Interconnection processes for co-located large load and generation resources are limited and inconsistently defined, creating uncertainty for developers as well as grid operators.

There is currently no clarity around which entities will regulate and harmonize the various large load interconnection processes (states, FERC, NERC, utilities, ISOs/RTOs) to promote the adoption of core process elements:

- Defined process milestones and timelines
- Defined site-control requirements (e.g., land ownership, leases, permits, easements)
- Milestone-based study fees and financial securities
- Penalties for late-stage withdrawal of interconnection applications
- Cluster study processes and open window application processes
- Option for the interconnection customer to build the interconnection substations and transmission lines to the utility's equipment and construction standards

### A Lack of Coordination Between Utilities and ISOs/RTOs

Large load facilities are connecting across all levels of the electricity system through multiple, often separate, interconnection processes. Distribution- and sub-transmission-connected large loads are typically handled directly by utilities; transmission-connected large loads may follow utility-led transmission interconnection processes; and co-located large load and generation configurations may be studied through generation interconnection frameworks administered by ISOs and RTOs. This fragmented structure and lack of coordination creates duplication of effort and makes it difficult to ensure consistent visibility into cumulative system impacts, maintain reliability of the bulk power system, and apply consistent study assumptions, data exchange, timelines, and upgrade determinations across utilities, transmission owners, and ISOs/RTOs. A key question is:

- How can utilities and ISOs/RTOs ensure close coordination and information-sharing between all involved stakeholders?

### Lack of Consensus Around Open Questions for Interconnection Studies

The studies performed during the interconnection process are essential to understanding the grid impacts of new large load facilities. In addition to their size, large loads connecting to the grid today are significant in that they have sophisticated equipment and systems and have new operational characteristics. This requires that detailed steady-state, positive-sequence phasor-domain (PSPD), short-circuit, and even electro-magnetic transient (EMT) studies be performed during the interconnection process to adequately evaluate the impacts these facilities have on the bulk power system. However, there are many open questions surrounding the studies' use, including:

- Which grid reliability studies will be conducted for large loads (e.g., steady state, PSPD, short circuit, EMT)?
- Which entities will run these studies (utilities, ISOs/RTOs, others)?

- What new contingencies and operational conditions need to be studied?
- How will co-located large load facilities with paired generation be studied (e.g., gross or net with what conditions)?

## Incomplete or Absent Performance Requirements

Performance requirements for large load facilities are incomplete or absent throughout the industry at the NERC, state, ISO/RTO, and utility levels, leaving gaps in the reliability oversight framework for ensuring bulk power system reliability.

- What performance requirements will be placed on the large load facilities at the very beginning of the interconnection process and throughout commercial operation (e.g., voltage and frequency ride-through, power factor requirements, ramp limits)?
- Which entities will define, mandate, harmonize, and enforce these performance requirements (utilities, states, ISOs/RTOs, NERC, FERC)?
- How and when during the interconnection process will conformity with these performance requirements be assessed? How will conformity be verified or tested during commissioning and monitored during the lifetime of the project?

## Interconnection Costs and Network Upgrades

Cost allocation frameworks for large load interconnection substations/lines and transmission network upgrade costs lack the structure and clarity needed to protect all customers.

- How will allocation for direct interconnection costs and associated network upgrade costs be addressed for large load facilities?

## Slow Speed of Large Load Interconnection

Speed to power is one of the primary drivers for most large loads today. As the industry evolves to handle these new facilities, the large load interconnection process must also evolve to become more efficient and consider new capabilities and grid interconnection arrangements that large loads bring with them.

- How can interconnection processes incentivize “bring your own generation” (BYOG)?
- How will transmission capacity limits and flexibility of large loads (non-firm transmission service) be factored into the large load interconnection process at different levels of the electricity system (distribution, sub-transmission, transmission)?

- How will new grid-service offerings (such as non-firm service, flexible service, surplus service) for large load interconnection at the transmission and distribution levels affect grid planning and operational studies?

## Recommendations

Based on the Large Loads Task Force's review of current practices and challenges and drawing from the experience and expertise of task force participants including system operators, utilities, data center operators, regulators, and researchers, this report offers a set of recommendations to create a more harmonized, transparent, and efficient interconnection framework for large loads. The recommendations aim to preserve latitude for regional and local variation while establishing the consistency and rigor that large load integration demands.

### Large Load Interconnection Process Overall

- The entities that are responsible for large load interconnection processes can follow the recommendations in this report to create more uniform, transparent interconnection processes across the U.S. that will help improve efficiency and speed of large interconnections. It is recommended that the processes be based on clearly defined milestones with readiness requirements that provide credible indication of project viability, roles and responsibilities, timelines, and cost allocation frameworks.
- The potential for development of a FERC Large Load Interconnection Procedure (LLIP) can be explored that establishes a baseline framework for large load interconnection under FERC jurisdiction, analogous to existing generation interconnection procedures, with transparent processes, defined milestones, timelines, and cost responsibility frameworks. States and non-FERC jurisdictional entities could consider adapting the LLIP for large load interconnections over which they have authority.
- The large load interconnection application packages, site control (land ownership, signed lease agreements, or options to purchase or lease land of sufficient size for the facility), and financial readiness requirements can be applied to filter speculative interconnection requests and reduce queue congestion driven by large load projects that lack the commitment to proceed. Harmonizing these requirements insofar as possible across the nation will further help to improve the clarity and efficiency of the large load interconnection process.
- Consistent financial security requirements can be implemented across all interconnection providers, including milestone payments and withdrawal penalties, to mitigate the risk of stranded infrastructure investment and ensure appropriate utility cost recovery from large loads.
- Material modification rules can be finalized to maintain the integrity of interconnection queues and study processes as project configurations evolve, balancing the need to accommodate technological change with the need to preserve study integrity and planning assumptions.
- Expanded use of hosting capacity maps early in the siting and interconnection process can guide large load developers toward locations with available grid capacity, reducing initial study complexity and queue processing time.

### Large Load Interconnection Process Coordination

- Coordination among utilities and ISOs/RTOs needs to be enhanced throughout the interconnection process, including formal information-sharing protocols and joint study procedures for facilities that interact with multiple grid layers.
- Queue transparency can be improved at both utilities and ISOs/RTOs, including harmonized treatment of duplicate requests and consistent application of interconnection requirements across service territories.
- Large load interconnections can be integrated into regional transmission planning processes, ensuring that the infrastructure needs of large load growth are reflected in long-term planning and cost allocation frameworks.

### Large Load Interconnection Process Studies

- When the volume of large load connection requests exceeds a preset level, utilities and ISOs/RTOs can transition to cluster study approaches for large loads, consistent with reforms already underway for generator interconnection. This approach improves study efficiency and reduces the compounding delays created by serial study queues.

- For every large load interconnection, steady-state, PSPD, and short-circuit studies need to be performed that meet applicable NERC, ISO/RTO, and utility study requirements.
- A screening process can be established to determine when certain large load facilities require EMT studies and those studies performed for the large load facilities identified.
- Harmonized reliability study methods can be developed for studying co-located load and generation, including conditions under which they are studied as a single entity.

## Large Load Interconnection Technical Requirements

- Clear performance and capability requirements for large loads can be developed that apply for the lifetime of these facilities. These include detailed technical modeling requirements for PSPD and EMT models that would be submitted as a part of the interconnection application and updated throughout the interconnection process as facility design and construction advances.
- Technical requirements and practices for assessing loads' conformity with the requirements can be unified across the U.S. grid to enable efficiency and consistency for all large load interconnections.
- NERC large load–specific reliability standards can be developed that address load modeling, performance and capability requirements, physical and cybersecurity, operational coordination, data sharing, emergency operating conditions, and other reliability topic areas. NERC has already started work to develop an interim set of requirements for large loads, to be followed by a more comprehensive applicable standards revisions effort.
- NERC can create an additional registration category that would specify which large loads would be subject to mandatory enforceable requirements within its regulatory area. This separation of large loads in the compliance space can allow for the more efficient creation of technology-specific requirements that will help enhance bulk power system reliability without overburdening traditional large loads (e.g., industrial loads such as steel and glass production) or creating insufficient requirements that fit all large load types. NERC has already begun the work of creating and defining this large load registered entity.

## New Solutions to Speed Up Large Load Interconnection

- Harmonized voluntary flexibility products can be developed, including provisional, surplus, and non-firm service options, to give large load customers more flexibility options and accelerate interconnection where firm service is not immediately available.
- Clear, consistent rules can be established for bring-your-own-generation arrangements and generation resources co-located with large loads. The rules will need to clearly define how a co-located resource is treated, modeled, and studied at each of the large load interconnection process milestones.

## Staffing Resources

- Utilities and ISOs/RTOs need sufficient staffing resources to process the growing volume and complexity of large load interconnection requests.

Taken together, these recommendations provide a practical and technically grounded pathway toward a large load interconnection framework that supports the reliable, efficient, and timely integration of large load facilities into the U.S. electric power system.

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# Introduction

The interconnection of large loads into the U.S. electric power system is advancing quickly, with an exponential rise in the number and magnitude of new large load interconnection requests. These interconnections are driving up load growth forecasts across the nation. For some utilities, large load growth could increase their peak demand to several times the current levels in the next decade (ERCOT, 2026c).

The U.S. Department of Energy (U.S. DOE) estimates that national electricity demand is likely to grow by 15% to 20% over the next decade and could double by 2050 under certain scenarios (U.S. DOE, 2025a). This trend represents a reversal of the long period of flat or declining electricity demand in many regions. These projections are largely driven by data centers, cryptocurrency facilities, industrial electrification, electric vehicle fleets, and other concentrated loads that require significant capacity and reliability. Most such large loads seek fast development and grid interconnection schedules.

Data centers represent the majority of new large loads. As of February 2026, Cleanview estimated that more than 650 planned data center projects would add over 176 GW of peak demand nationally (Thomas, 2026). This highlights that there is both a significant number of large load projects in the interconnection queues and those large load projects have very high demand. While many of the requested large load projects may never mature due to a variety of factors—including bulk power system construction times, high interconnection costs, speculative requests submitted into interconnection queues, supply chain issues, and changes in the data center industry and computer chip technology—future data centers are still likely to have a huge impact on peak electricity demand.[1]

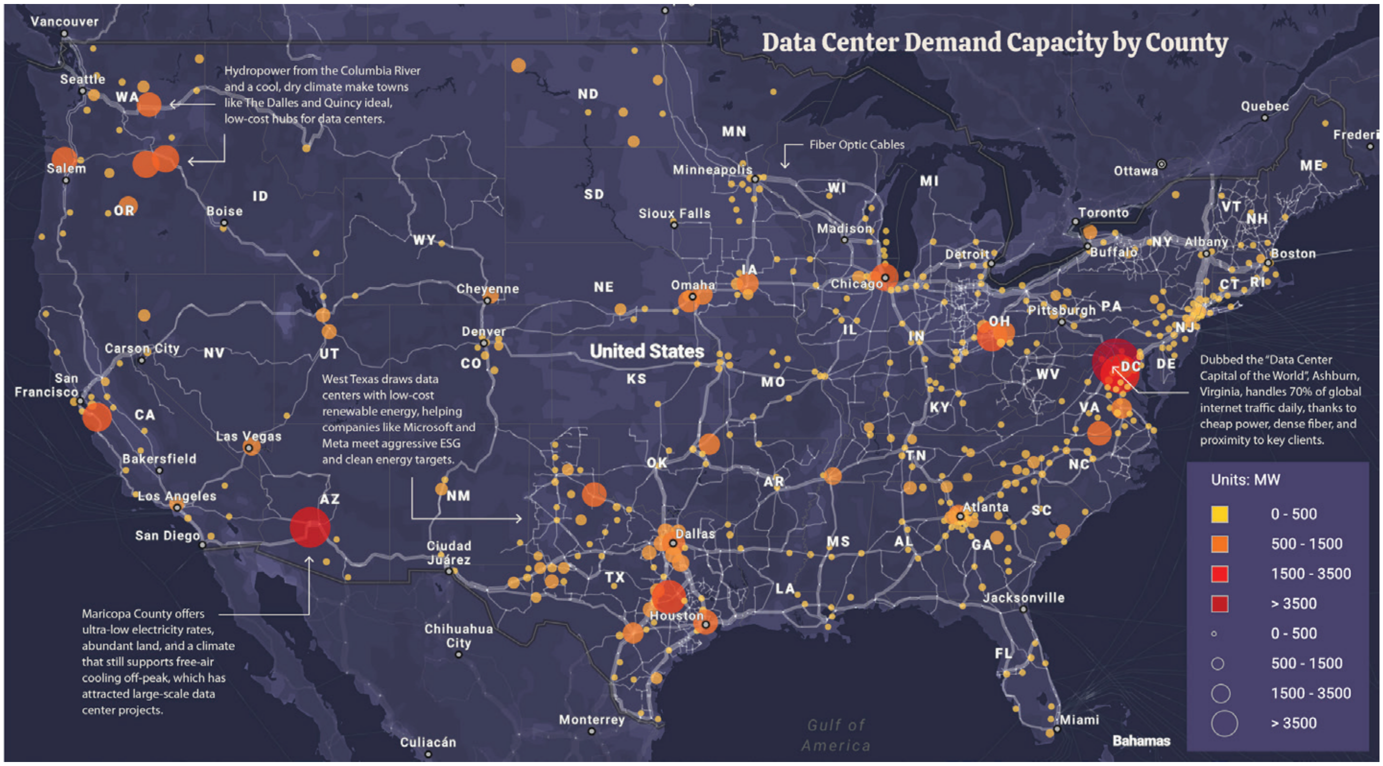
Currently, hundreds of gigawatts of potential large load capacity additions are sitting in interconnection queues across the nation. After a large load application completes the path through the queue and is deemed safe to interconnect, it may wait years until new grid facilities and upgrades are complete before it can physically connect to the grid at full capacity. Backlogs are particularly long in regions where new load interconnection requests are geographically concentrated due to favorable energy prices, available land, fast telecommunications links to major customer centers, available transmission infrastructure or potential for quick transmission expansion, and a robust local supply chain and hiring pool (see Figure 1, p.2). For example, as of March 2026, the Electric Reliability Council of Texas's (ERCOT's) large load interconnection queue contained over 410 GW of new load seeking to interconnect to the system (ERCOT, 2026c), and nearly 88% of those projects are data centers. The Midcontinent Independent System Operator (MISO) has more than 13 GW of potential new large load additions in its load interconnection queue (MISO, 2026a).

The rapid growth in both the scale and volume of large load interconnection requests presents important opportunities, as these projects can support economic development and technological innovation. However, large loads place unprecedented pressure on load forecasting practices, power system planning and operations, interconnection processes, and the ability to expand infrastructure on timelines that align with large load development. As large

1 Computer chip technology (such as graphics processing units) inside data centers is expected to continue to become more efficient and have more computational power as well as different operating characteristics.

FIGURE 1

## Geographical Concentration of Operational and Under-Construction Data Centers Across the United States, as of September 2025




**Data center projects (operational and under construction) are geographically concentrated in areas with favorable energy prices, available land, fast telecommunications links to major customer centers, available transmission infrastructure or potential for quick transmission expansion, and a robust local supply chain and hiring pool.**

Source: N. Routley, "Mapped: The Massive Network Powering U.S. Data Centers," *Visual Capitalist*, September 20, 2025, https://www.visualcapitalist.com/map-network-powering-us-data-centers/; map/data sourced from https://maps.nrel.gov/speed-to-power/.

**As large loads increasingly dominate queue activity in several regions, it will be essential to improve queue transparency, distinguish viable projects from speculative requests, and align grid build-out timelines with customer schedules to reliably accommodate this new era of electricity demand growth.**

loads increasingly dominate queue activity in several regions, it will be essential to improve queue transparency and management, distinguish viable projects from speculative requests, and align grid build-out timelines with customer development schedules to reliably accommodate this new era of electricity demand growth.

Where it exists, the large load interconnection process in the U.S. includes seven sequential phases: the pre-application phase, the interconnection application, initial screening and feasibility studies, a system impact study, a facility study, a signed interconnection agreement, and construction/commissioning. Within these seven phases is a great deal of variation around the specifics of who executes, who approves, what documentation and data submission are required, and what dictates the phase's timeline. The interconnection process is the starting point for which large loads will be able to interconnect to the grid and when. Uncertainties in the interconnection process delay timelines and may trigger additional study requirements, leading to higher costs for large load developers.

To identify current practices, gaps, and challenges and develop harmonized best practices for integrating large loads reliably and efficiently, the Energy Systems Integration Group (ESIG) launched the Large Loads Task Force, which convened a multi-stakeholder group of system operators, utilities, data center operators, regulators, and researchers.

The task force adopted the North American Electric Reliability Corporation's (NERC's) definition of a large load facility:

> Any commercial or industrial individual load facility or aggregation of load facilities at a single site behind one or more point(s) of interconnection that can pose reliability risks to the BPS [bulk power system] due to its demand, operational characteristics, or other factors. Examples include, but are not limited to, data centers, cryptocurrency mining facilities, hydrogen electrolyzers, manufacturing facilities, and arc furnaces (NERC, 2025a).

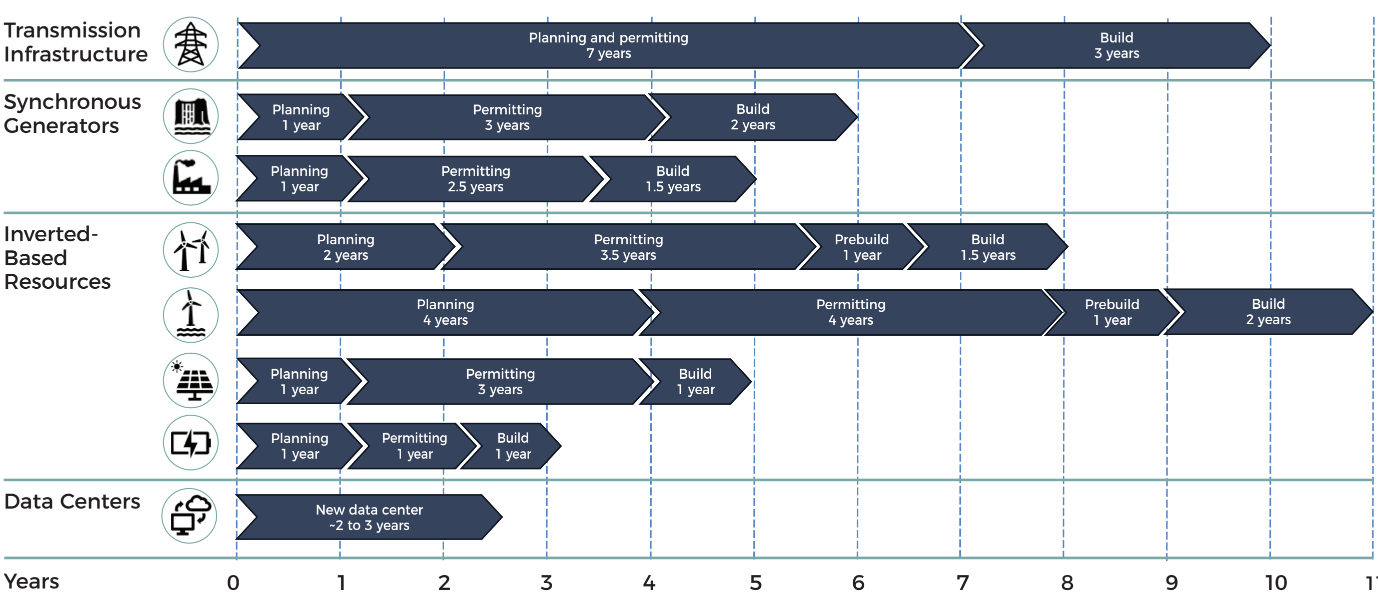
ESIG's Large Loads Task Force consisted of seven specialized project teams, each focusing on a key aspect of large load integration, from interconnection and operations to planning and market design. This report reviews current large load interconnection processes across the nation and identifies impediments, inefficiencies, and potential reliability risks related to current interconnection processes. It then (1) offers recommendations for modifying the interconnection process to become more harmonized, efficient, and transparent; and (2) addresses the unique operational and technical characteristics of new large loads, while providing flexibility in the process for specific local and regional differences.

## Issues with the Interconnection Process

While the proliferation of large loads represents an opportunity for economic development, it imposes significant stress on the grid. Figure 2 shows how new large loads such as data centers can be developed on relatively short timelines, much shorter than the time it takes to plan, permit, procure equipment for, and build transmission, distribution, and generation infrastructure to support these loads.

FIGURE 2

**Timelines to Develop and Build Grid Infrastructure and Large Loads**




**Data centers can be developed on relatively short timelines, much shorter than the time it takes to plan, permit, procure equipment for, and build transmission, distribution, and generation infrastructure to support these loads.**

Source: R. Quint et al., *Practical Guidance and Considerations for Large Load Interconnections* (Elevate Energy Consulting and GridLab, 2025), https://gridlab.org/wp-content/uploads/2025/07/GridLab-Report-Large-Loads-Interim-Report.pdf.zip.

Additionally, large load facilities pose challenges to the bulk power system that include:

- Reliability risks for planning, operations, and resource adequacy due to the rapid, high-volume interconnection of large loads (NERC, 2025a)
- Disputes between large load entities and transmission owners over interconnection rights and obligations
- Potential cost allocation concerns where speculative large load growth could trigger new infrastructure investments that are not sufficiently utilized to recoup costs from those loads
- Impacts on utility customer rates, wholesale rates, and system planning

Large load customers frequently struggle to understand interconnection timelines, costs, and technical requirements, and therefore sometimes submit multiple applications for a single facility to hedge the uncertainty. Utilities then must process redundant requests, which stresses staff resources that study and process interconnection requests for large loads, and causes delays with significant economic consequences. Speculative large load interconnection requests and uncertainties also send false signals such as inflated load forecasts to utilities and wholesale markets, misleading investment decisions.

The jurisdiction, applicable entities, and coordination of large load interconnection processes and queues are complex and rapidly changing. Traditionally, utilities and other transmission providers have been responsible for load interconnections, including for large loads, under either state or federal regulations and tariffs. These historical load interconnection processes remain today but may be ill-equipped to handle the quantity and size of today's loads. Additionally, there's an emerging need for closer coordination on large interconnection with independent system operators (ISOs) and regional transmission organizations (RTOs). Industry experience to date has highlighted the following important gaps, inconsistencies, and unresolved questions related to the large load interconnection:

- Load interconnection processes vary significantly across utilities and regions, with many jurisdictions relying on ad hoc procedures that were not designed for facilities of the scale or complexity of current large loads.

- There is significant variation in the scope and complexity of studies to determine whether the large load can be accommodated at its requested point of interconnection as well as variation in the interconnection cost and timing.
- There is inadequate coordination and information-sharing during the large load interconnection process between utilities and ISOs/RTOs. This often results in duplicated efforts, conflicting study assumptions, load forecasts that vary widely and change rapidly, and delayed processing of interconnection applications.
- There are open questions surrounding interconnection studies, including which grid reliability studies will be conducted for large loads, which entities will run these studies, what new contingencies and operational conditions need to be studied, and how co-located large load facilities with paired generation will be studied.
- Performance requirements for large load facilities are incomplete or absent throughout the industry at the NERC, state, ISO/RTO, and utility levels, leaving gaps in the reliability oversight framework for power systems.
- Cost allocation frameworks for large load interconnection substations/lines and transmission network upgrade costs lack the structure, clarity, and consistency needed to protect all customers.
- Interconnection processes for large loads can take a great deal of time, due in part to limited and inconsistently defined pathways for the interconnection of co-located large load and generation resources, and flexible interconnection options not uniformly available or well understood across the industry.

## Report Organization

Given the rapid increase of large load interconnection requests in most regions, as well as the rise of combined facilities that include both a large load and co-located generation resource, utilities and regional grid operators are beginning to solve these challenges by collaborating and sharing responsibilities. These evolving issues vary by region, and the recommendations in this report focus on core aspects of the large load interconnection process, regardless of which entity manages it.

**Given the rapid increase of large load interconnection requests in most regions, as well as the rise of combined facilities that include both a large load and co-located generation resource, utilities and regional grid operators are beginning to solve these challenges by collaborating and sharing responsibilities.**

This report provides an overview of how large load interconnections are handled in the U.S. at both the transmission and distribution levels, including regulatory gaps, queue procedures, and timelines. The findings are based on information collected by the ESIG Large Loads Task Force from large load developers, owners, and operators; utilities; and ISOs/RTOs about what is working well and what challenges they face.

The next section of the report gives an overview of the large load interconnection process, including what this looks like for utilities of different types, the central role of interconnection studies, and lessons the industry can learn from recent experience with generation interconnection. The following section discusses the transmission-connected large load interconnection process from the perspectives of utilities and ISOs/RTOs. The report then discusses possible types of federal action on large load interconnection based on lessons learned from earlier generator interconnection reforms for inverter-based resources and offers recommendations for large load interconnection processes. Then, recognizing that some large loads may choose to interconnect at the distribution level, the report turns to interconnection processes for distribution-connected large loads, identifying gaps and challenges in existing processes and providing recommendations for future improvements. The report concludes with a summary of the recommendations of the Large Loads Task Force, intended to create a more harmonized, transparent, and efficient interconnection framework for large loads.

# Overview of the Large Load Interconnection Process

Transmission-level large load interconnections are rapidly reshaping the planning and operational landscape of the bulk power system. Unlike traditional retail load growth that is incorporated gradually over time, today's large load projects are rapidly entering the system through discrete, high-capacity requests to utilities. These projects include the many large load facilities of more than 1 GW being planned and built across the country. Given their size, these new large load facilities materially affect regional reliability, transmission expansion needs, and resource adequacy. There is an urgent need to develop a systematic interconnection process framework with clearly defined milestones akin to that applied to the interconnection of generation facilities.

Traditionally, utilities have been responsible for load interconnections, including of large loads, under either state or federal regulations and tariffs. This approach was sufficient since large load interconnection requests were rare and geographically distributed. With the increased

number, size, and geographical concentration of today's large loads, their impacts on the bulk power system are increasing and there is a growing role for ISOs/RTOs in the large load interconnection process.

While there are diverse operating structures and regulatory environments across the industry, a complete large load interconnection process, which exists only in a minority of cases, can be distilled into seven distinct phases or milestones (Figure 3, p. 9), discussed in the next section.

## Milestones Distilled from Currently Implemented Large Load Interconnection Processes

The following milestones have been synthesized from a review of the few holistic and currently active large load interconnection processes. Some regions use only a subset of these phases, and the actual implementation and details for each step vary widely. At a high level these milestones form a solid framework for a systematic large load interconnection process and can be adopted by areas that are just starting to develop their large load interconnection processes.

### Milestone 1: Pre-Application Phase

Large load customers engage with utilities early in the process to discuss their tentative plans for load interconnection, including project details, siting, and other plans. Utilities share their expectations for interconnection timelines, requirements, processes, and more. This allows the utility/ISO/RTO and the customer to gain a mutual understanding and align on expectations.

### Milestone 2: Interconnection Application

The large load customer submits a formal interconnection application with details about demand size, location, technical aspects (design, diagrams, models, etc.), and load growth trajectory, accompanied by financial deposits.

### Milestone 3: Initial Screening and Feasibility Study

The utility conducts high-level viability assessments for the proposed large load interconnection, focused on items such as the voltage level required for interconnection, access to nearby transmission or distribution

infrastructure, potential direct-connect network impacts, the need for broader network upgrades, and known obstacles or issues.

### Milestone 4: Large Load System Impact Study

The utility performs detailed reliability studies (see the section "Interconnection Studies") to quantify the effects the large load has on the transmission system and, if applicable, the distribution system. The studies analyze the load's impacts on thermal overloading, system voltages, stability, and other reliability factors. They also determine the necessary system upgrades needed to alleviate any identified adverse impacts from the large load on the system.

### Milestone 5: Large Load Facilities Study

The utility performs a study focused on the detailed engineering designs, substation configuration, protection system upgrades, and upgrades required for direct-connect infrastructure modifications. This information is an input into the construction phase of the project.

### Milestone 6: Signed Interconnection Agreement

The utility/ISO/RTO and customer sign an agreement to formalize the terms and conditions for interconnection. All parties draft and negotiate the terms, outlining roles and responsibilities, cost responsibility, schedule, and operational performance expectations, as well as ensuring compliance with regulatory requirements and other industry standards.

### Milestone 7: Construction and Commissioning

The large load customer constructs the facility itself. Depending on their agreement, the utility and/or customer may construct the electrical facilities required to connect the load. The utility also makes any broader network upgrades required to connect the facility reliably. The load customer conducts testing and commissioning procedures to verify the facility's readiness. The utility may require documentation and verification that the facility is operating reliably and is compliant with applicable requirements.

### Additional Considerations: Post-Commissioning Monitoring and Compliance

While the post-commissioning phase is outside of the interconnection process itself, it is important to cover it here for completeness. After a large load facility has been commissioned and started commercial operation, the utility and large load customer each monitor the reliability of the facility and adherence to the requirements and procedures as applicable. Post-commissioning monitoring equipment (e.g., power quality meters and disturbance recorders) needs to be installed to monitor and analyze the large load facility's performance. Periodic review may be performed by the utility or customer to verify compliance with applicable requirements.

## Differences in Transmission Interconnection Processes for Different Utility Types

The U.S. electric utility industry operates under a complex set of organizational structures, each shaped by different power system characteristics, levels of inverter-based resources (IBRs) and large loads, regulatory environments, ownership models, and operational philosophies. This section examines the large load interconnection processes across four distinct utility types and discusses the nuances of how organizational structure can directly impact process efficiency, customer experience, and system reliability outcomes.

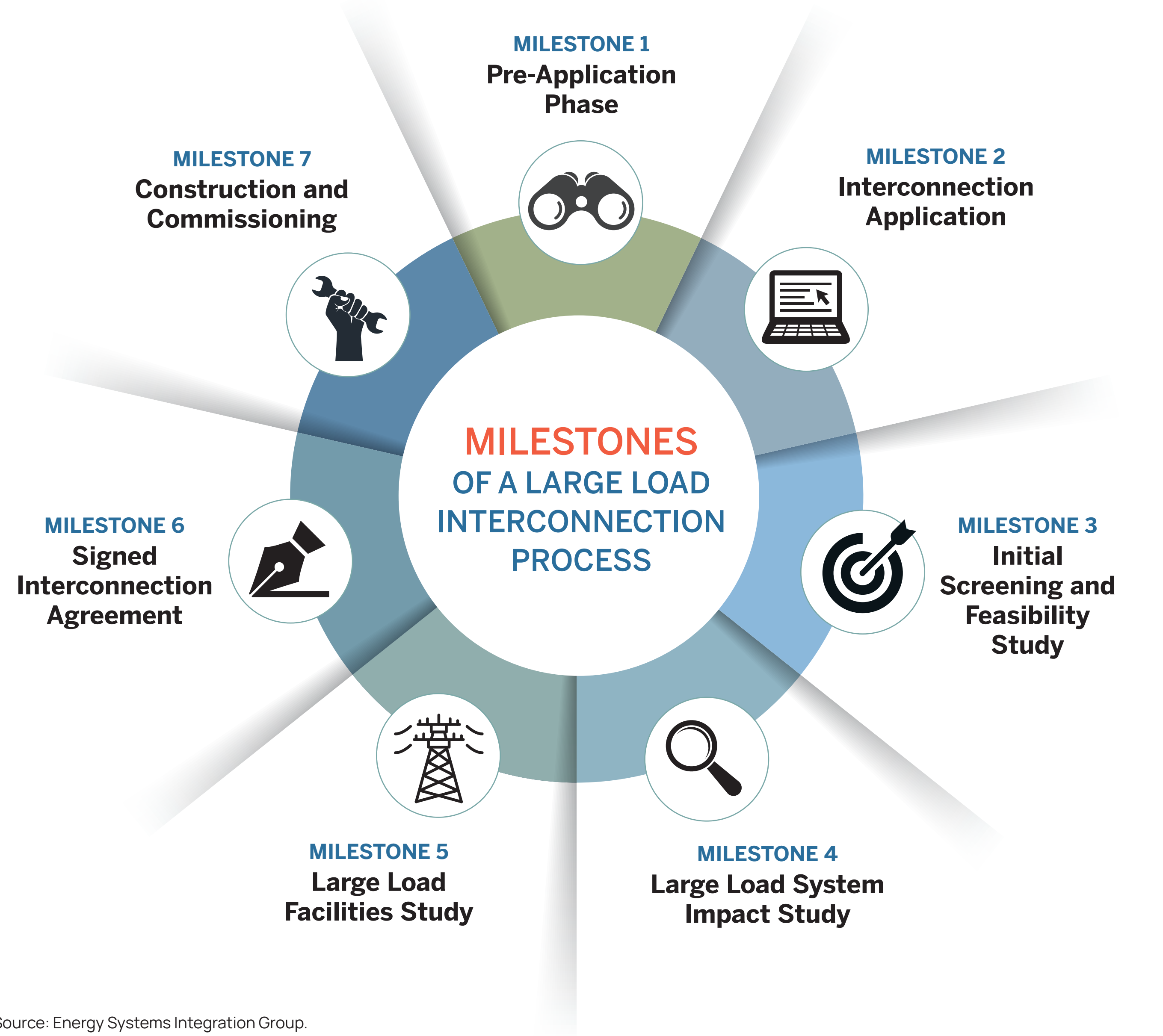
### Large Load Interconnection Processes for Different Utility Types

The following four utility types have different considerations and practices for interconnecting large loads, with the differences primarily driven by whether the utility is within an ISO/RTO area and whether the utility owns generation:

- **Network-only utilities** operate primarily within ISO/RTO markets and do not own generation assets. Generation and load interconnection processes in their system need to be heavily coordinated with the ISO/RTO to ensure coordinated transmission planning efforts and adequate load forecasting and generation resource availability/adequacy.

FIGURE 3

## Phases (Milestones) of a Large Load Interconnection Process




Source: Energy Systems Integration Group.

- **Vertically integrated utilities within ISO/RTO markets** have many similarities to the transmission- and network-only utilities, with the core difference being that the vertically integrated utility is responsible for securing or building enough generation to serve the load in its service territory, including large load interconnections. Both generation and large load interconnections need to be coordinated with the ISO/RTO. Vertically integrated utilities' interconnection processes must satisfy both their own internal requirements and external (ISO/RTO) obligations, creating complex regulatory and operational interfaces that require sophisticated coordination mechanisms.
- **Vertically integrated utilities outside of ISO/RTO markets** maintain full control over their

**Vertically integrated utilities' interconnection processes must satisfy both their own internal requirements and external (ISO/RTO) obligations, creating complex regulatory and operational interfaces that require sophisticated coordination mechanisms.**

load interconnection process, from initial application through energization. They coordinate internally between transmission, distribution, and generation planning functions. Operating outside of ISO/RTO markets, they retain full responsibility for system planning, operations, and reliability, including resource adequacy. This structure enables streamlined internal decision-making but requires comprehensive in-house expertise across all system functions, including all modeling and study activities. Their interconnection processes reflect this self-contained approach to system management; however, these utilities still require close coordination with neighboring transmission entities that may be affected by newly interconnecting generators or large loads.

- **Cooperative utilities (co-ops)** typically serve smaller service territories, but many are also facing growing numbers of large load interconnection requests that can significantly impact their systems. Distribution co-ops rely on generation and transmission cooperatives or other wholesale power suppliers for bulk power supply and often depend on a third-party or jointly owned transmission system for delivery and regional grid access. The electric cooperatives operate under a member-ownership model, emphasizing service to rural and suburban communities. Their not-for-profit structure and democratic governance create decision-making processes focused on member benefits rather than shareholder returns. As a result, large load interconnection requests may receive heightened scrutiny regarding cost allocation, impacts on existing members, required system upgrades, and long-term power supply obligations, and may also involve additional coordination among local co-ops, generation and transmission providers, boards, and transmission partners compared with more vertically integrated utilities.

While the technical challenges of integrating large loads remain consistent, the procedural, financial, and regulatory approaches vary significantly based on utility type and institutional requirements. Understanding these differences is crucial for developing harmonized processes that can accommodate diverse organizational models while maintaining interconnection process effectiveness.

As mentioned above (Figure 3, p. 9), the sequential phases of the large load interconnection process—pre-application phase, interconnection application, initial screening and feasibility study, system impact study, facility study, signed interconnection agreement, and construction and commissioning—create a fundamental structure for every interconnection request. While these seven phases are universally present, the specifics of who executes, who approves, and what dictates the timelines of each phase highlight the differences between the four major utility types, summarized in Table 1 (p. 10). The differences in interconnection process approaches highlighted in the table come from entities that already have significant experience with interconnecting large loads and the lessons they have learned to date.

**While the technical challenges of integrating large loads remain consistent, the procedural, financial, and regulatory approaches vary significantly based on utility type and institutional requirements.**

## Evolving Role of ISOs/RTOs in the Large Load Interconnection Process

ISOs/RTOs and utilities have distinct roles in ensuring bulk system reliability and resource adequacy, including identifying the transmission facilities required to reliably serve new loads and ensure deliverability to new generation. Historically, load interconnection processes for transmission-connected loads were primarily run and managed by utilities directly, with little engagement with the ISO/RTO when a load was interconnecting in an ISO/RTO region.

TABLE 1

## Large Load Interconnection Process Variations for Different Types of Utilities

| Utility Type | Variations in Approach |
|---|---|
| **Transmission- and distribution-only utilities and vertically integrated utilities within ISO/RTO markets** | • **Pre-application phase:** There may be coordination between the utility and the ISO/RTO before the customer formally submits the interconnection application, including a kick-off call to review the scope of studies with all relevant documents and data that the customer has submitted.<br><br>• **Limited customer identification/interaction:** Currently, limited pathways of communication exist between the ISO/RTO and large load customers, often because the large load customers historically have not had to interface directly with the ISO/RTO but rather just with the interconnecting utility. The interconnecting utility then informs the ISO/RTO of the large load interconnection when requesting the necessary transmission upgrades or expansion.<br><br>• **Large load application and initial screening:** The customer works with the utility to complete a non-disclosure agreement, providing project application details, data survey, a one-line diagram, and site control information (e.g., land ownership, leases, permits, easements). This is followed by a point of interconnection review and realistic in-service date guidance. Increasingly there is a need to coordinate large load interconnection requests with ISOs/RTOs at this early interconnection phase.<br><br>• **Study coordination:** Interconnection studies and updates to load models need to be coordinated with ISO/RTO planning departments for broader regional visibility. If the entity is transmission-only, it needs to further coordinate with assigned distribution service providers or load-serving entities in the geographical area. Large load customers may sometimes also be required to submit load interconnection requests to distribution service providers or load-serving entities.<br><br>The ISO/RTO may review the utility's study report or perform its own "do no harm assessment" and assign supplemental project numbers (for tracking and planning purposes),[2] and then the project proceeds to an interconnection agreement with the utility. These studies need to be coordinated with a kick-off meeting for scoping, continued collaboration throughout the study review process, and a final approval from the ISO/RTO.<br><br>• **Broader visibility of large loads in an area spanning multiple utility service areas:** Building on the previous point, since ISOs/RTOs usually have a broad view of their systems, they are best positioned to flag potential system-level reliability issues for transmission owners that narrower service-area studies could miss.<br><br>• **Timeline management:** ISO/RTO studies or study review cycles and cluster processes, when they are implemented for large loads, increasingly affect process timelines. |
| **Vertically integrated utilities outside ISO/RTO markets** | • **Direct customer interface:** The utility serves as a single point of contact for interconnection customers.<br><br>• **Streamlined decision-making:** These utilities are able to take advantage of internal coordination between all departments across transmission, generation, and distribution, which enables faster decision processes.<br><br>• **Customizable system impact studies:** Vertically integrated utilities outside ISO/RTO markets have the ability to fully customize study scope based on expected system impacts from each project without having to coordinate with an ISO/RTO.<br><br>• **Integrated planning:** Ideally, the vertically integrated utility coordinates large load interconnection processing across all system functions within the company. Critically, very large load interconnection studies must still be closely coordinated with neighboring utilities to ensure that appropriate system-wide analysis is performed by all impacted systems. |

— CONTINUED —

2 One example of growing ISO/RTO coordination is within ERCOT, where, due to the high number of large load interconnection applications, the "clustering" or "batching" interconnection process was developed (and currently being finalized) in which multiple potential large loads and generators in a common geographical or grid topological region will be studied by the ISO together to capture the operational interactions and collective infrastructure requirements across that group of projects.

TABLE 1

## Large Load Interconnection Process Variations for Different Types of Utilities CONTINUED

| Utility Type | Variations in Approach |
|---|---|
| Cooperative utilities | • **Member-focused approach:** The large load interconnection process at cooperative utilities considers the impacts on existing cooperative members.<br>• **Resource-limited studies:** The cooperative may rely on external consultants or generation and transmission cooperative expertise, and coordinates with the ISO/RTO where applicable.<br>• **Community impact assessment:** The large load interconnection process evaluates local economic and social impacts.<br>• **Collaborative decision-making:** Board-level involvement is common for major interconnection decisions, particularly when the size of the large load customer exceeds the size of the host cooperative utility.<br>• **Load interconnection requests recieved by the utility:** The distribution cooperative utility receives the request, performs initial checks, and refers to the relevant transmission owner (or generation and transmission cooperative) when transmission impacts arise.<br>• **Coordination of the resource adequacy assessment:** The co-op has to work with other utilities and supply resources to determine whether the region has enough resources to serve the new large load in addition to existing and other new loads. |

Source: Energy Systems Integration Group.

As alluded to in the previous sub-section, this situation is now changing because of the impacts today's large loads have on grid planning and operation that need to be carefully considered at both the utility and ISO/RTO levels. Large load interconnection spans the interface between utilities and ISOs/RTOs. Utilities still manage the official large load interconnection process and interconnection queues, handling project intake, project screening, and local transmission impacts; defining interconnection costs; and developing construction plans to implement any required direct transmission interconnection facilities and transmission system upgrades. They are also responsible for tracking milestone requirements such as site control (land ownership, signed lease agreements, or options to purchase or lease land of sufficient size for the facility), financial commitments and advancement through the queue, the projects that withdraw or get removed from the queue, and other logistical aspects similar to generation interconnection queues. However, coordination with an ISO/RTO now needs to take place for the purpose of impact studies and study reviews, as well as regional coordination for broader system impact assessment (for clusters of new projects), transmission planning, and resource adequacy assessments, which are primary responsibilities for ISOs/RTOs.

## Interconnection Studies

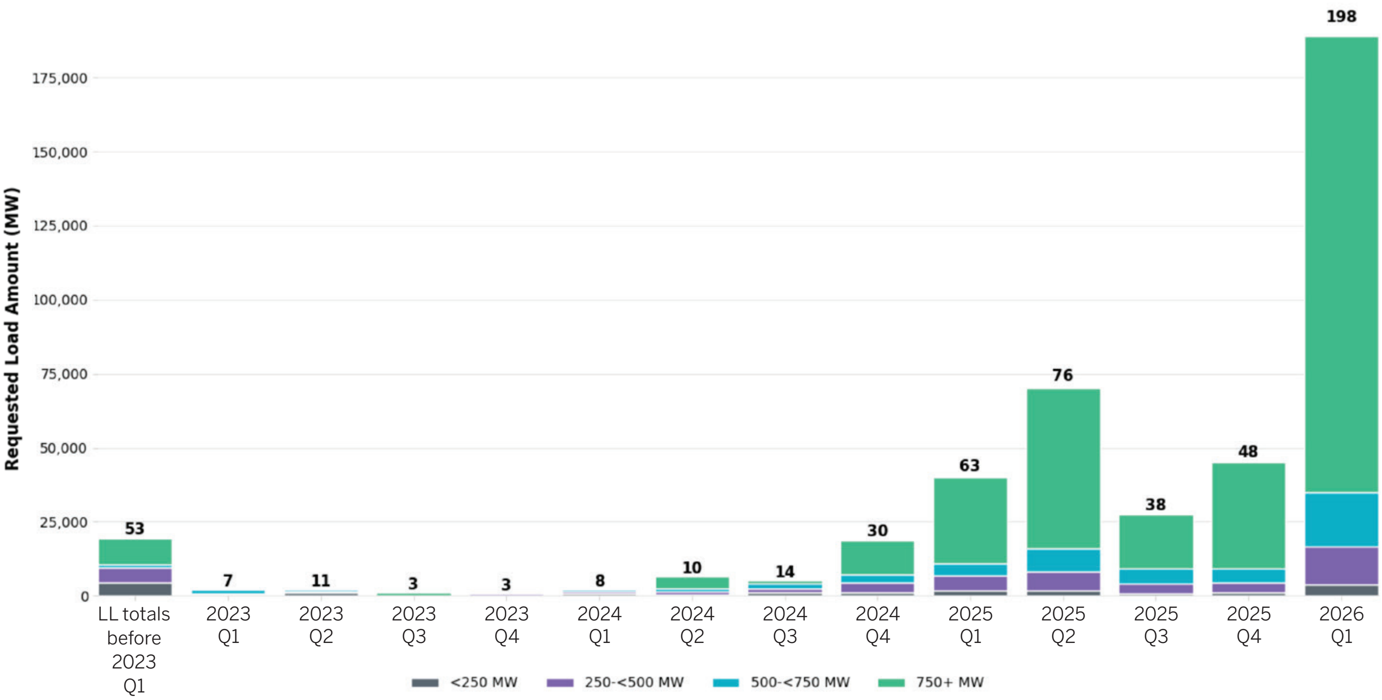
At the heart of the interconnection process are a variety of technical studies conducted to determine whether and how the new large load can be connected to the grid without causing harm to either the grid or its existing customers. These detailed, complex technical studies are performed by utilities and/or ISOs/RTOs. Technical study results inform what kind of new transmission infrastructure and generation infrastructure may be needed to serve the new large load, what mitigating equipment or behaviors are needed at the new large load facilities, and how the grid can be protected from the new load facility.

### A Need to Capture Reliability Risks with New Large Loads in System Impact Studies

New large load facilities may require additional technical studies, analyses, and mitigating solutions that have historically not been needed for loads. These new loads are equivalent in size to some of the largest generation facilities on the electricity system. However, most current load interconnection processes were designed for loads under 50 to 100 MW and have not typically required the information, data, and modeling necessary to handle the

FIGURE 4

## Number of Large Load Interconnection Project Applications in ERCOT from Q4 2022 Through Q1 2026




Source: Electric Reliability Council of Texas, "Large Load Interconnection Status Update," March 26, 2026, https://www.ercot.com/files/docs/2026/03/27/March-TAC-Report-Updated_03262026.pptx.

added complexity of new large load projects and their interconnection requests. Figure 4 shows the magnitude of this challenge through the rapid increase of large load interconnection applications and evolution of projects' size in ERCOT from late 2022 through Q1 2026 (ERCOT, 2026c).

The industry is learning some hard lessons from the existing fleet of large loads about the consequences of insufficient or inaccurate technical studies to support large load interconnections to the bulk power system.[3] In July 2024, a normally cleared grid fault in northern Virginia triggered the sudden loss of more than 1,500 MW of data center load across 60 facilities that switched nearly simultaneously to back-up power via uninterruptable power supplies (UPSs), because they were designed to disconnect from the grid after a preset number of voltage excursions (NERC, 2025b). The disconnected load did not come back completely until a few hours later. This and other similar disturbance events, covered in the ESIG Large Loads Task Force report *Large Load Disturbance Events*,[4] underscore the operating risk that a large fleet of large loads poses to power grid reliability (NERC, 2025c).

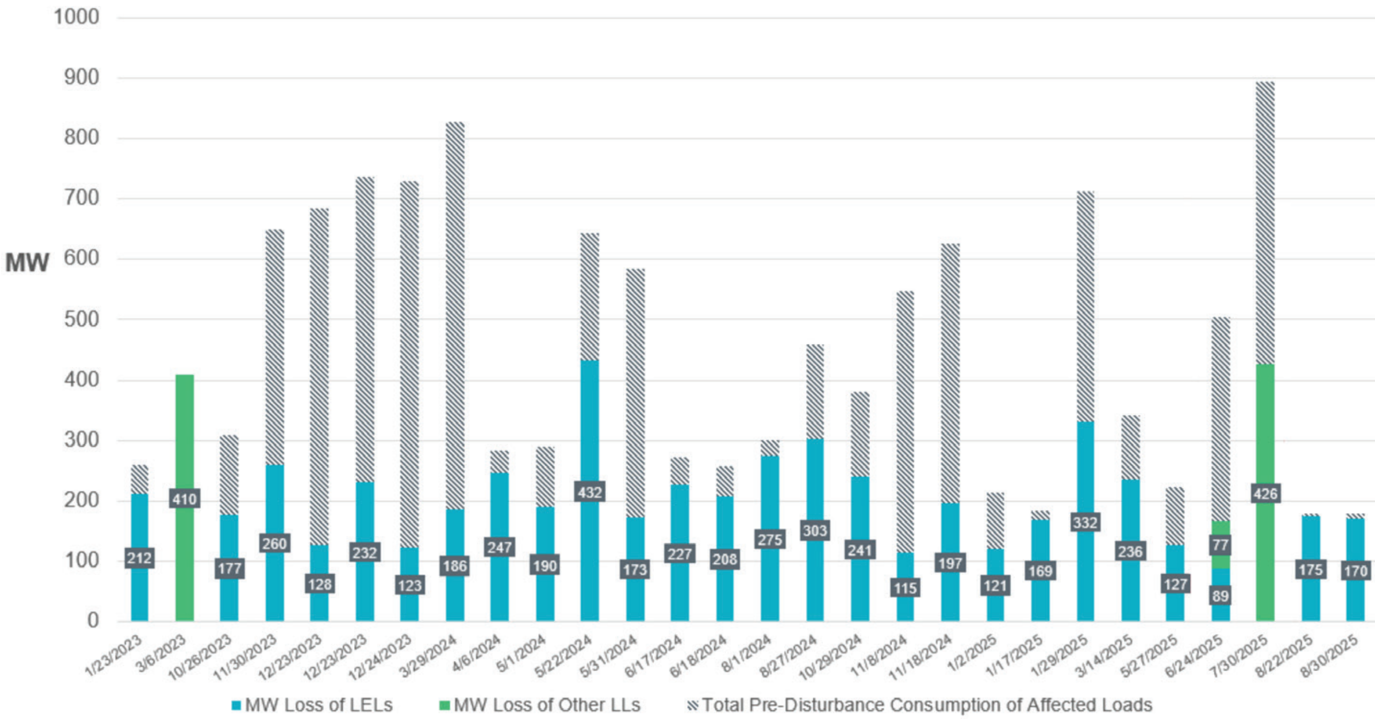
Sudden and frequent drops in electricity usage by large load facilities under 1 GW in size (see Figure 5, p. 14) for an ERCOT example) are also challenging system stability. While these specific disturbances did not result in widespread impact to the bulk power system themselves, the critical concerns are that many different large load

3 See the ESIG Large Loads Task Force reports *Large Load Performance Requirements: Current Practices and Recommendations* (https://www.esig.energy/reports-briefs/large-load-interconnection-performance-requirements/); *Large Loads: Behaviors, Capabilities, and Limitations* (https://www.esig.energy/reports-briefs/large-loads-behaviors-capabilities); *Reliability Impacts of Large, Power Electronics–Interfaced Loads* (https://www.esig.energy/reports-briefs/large-loads-reliability-impacts); and *Large Load Disturbance Events* (https://www.esig.energy/reports-briefs/large-load-disturbance-events/).

4 See https://www.esig.energy/reports-briefs/large-load-disturbance-events.

**FIGURE 5**

## ERCOT Large Load Loss/Reduction Events Due to Poor Ride-Through Capability, 2023 to August 2025




**From January 2023 through August 2025 the Electric Reliability Council of Texas experienced many sudden and frequent drops in electricity usage by large load facilities under 1 GW in size, which may challenge the system stability.**

Source: Patrick Gravois, "ERCOT Recent Large Load Loss/Reduction Events," Presentation to ERCOT Large Load Working Group, October 24, 2025, https://www.ercot.com/files/docs/2025/10/22/ERCOT-Recent-Large-Load-Events_LLWG_24Oct2025.pptx.

facilities all experienced the issues at the same time, and the size of these disturbances may increase with the continued proliferation of large loads. Additionally, the disturbances are occurring unexpectedly because these large load behaviors are not captured in current models of the large load facilities that are used during interconnection, planning, or operations studies (Hobbs, 2025).

Another system stability concern with large loads is the emergence of forced power consumption oscillations, rapid fluctuations in power demand at the grid connection point of some large load facilities, particularly certain artificial intelligence (AI) data centers and some crypto-mining facilities. The resulting behavior can range from very fast oscillations in the 10 to 50 Hz range to slower cycling between roughly 0.1 and 2.5 Hz, and may appear intermittently or increase as facility loading rises. In ERCOT, for example, one large electronic load showed 23 Hz oscillations that increased from about 15 to 20 MW peak-to-peak at lower operating levels to around 50 MW at higher loading. A similar event was reported in the Dominion Energy system, where sustained oscillations near 14.7 Hz were linked to interactions between a data center UPS system and changing grid conditions.[5] The primary concern for the power system is that these oscillations could excite the bulk system modes, including sub-synchronous torsional interactions in synchronous generators, which can damage synchronous generator equipment, or wider-area electromechanical oscillations, depending on their frequency and where they occur on the network.[6] There is a need for cautious, deliberate

5 For more information, see the ESIG report *Large Load Disturbance Events*, https://www.esig.energy/reports-briefs/large-load-disturbance-events/.

6 For more information about power system oscillations, see ESIG's report *Diagnosis and Mitigation of Observed Oscillations in IBR-Dominant Power Systems: A Practical Guide* at https://www.esig.energy/oscillations-guide/.

processing and analysis of large load interconnection requests to ensure that technical problems such as voltage and frequency ride-through and forced or natural resonant oscillations caused by large load operations do not compromise bulk power system reliability.

In response to reliability events such as these, NERC issued a Level 2 Alert, "Industry Recommendation: Large Load Interconnection, Study, Commissioning, and Operations" to all grid operators and transmission entities. NERC warned that "rapid, major swings in load, experienced both in typical operations as well as in response to grid disturbances, can impact the bulk power system's ability to maintain frequency, regulate transmission voltage, and otherwise maintain stability" (NERC, 2025c, 1). The summary of responses to the Level 2 Alert emphasized that transmission planners and operators often receive late or incomplete information about large load projects, including uncertain in-service dates, phased build-outs, changing demand profiles, and limited visibility into ride-through capability, behind-the-meter generation, or control systems, which can undermine the accuracy of technical studies during the interconnection process and lead to multiple restudies (NERC, 2026a). NERC also noted that representations of loads in traditional static load models may be insufficient for some large electronic loads whose dynamic behavior during faults, voltage disturbances, or automatic recovery following grid events can materially affect reliability, creating a need for better large load modeling and closer coordination among load developers, utilities, and reliability coordinators. Overall, the NERC alert's message was that interconnection processes, data requirements, and study methodologies need to evolve quickly to keep pace with the scale, speed, and technical characteristics of today's large loads. A NERC Level 3 Alert, "Essential Actions: Computational Load Modeling, Studies, Instrumentation, Commissioning, Operations, Protection, and Control" then followed, aiming to (NERC, 2026c):

- Improve the modeling and study of large computational loads in both planning and operational time frames, including simulations in the positive-sequence phasor and electromagnetic transient (EMT) domains, and increase visibility into load performance through enhanced monitoring, disturbance recording, and instrumentation.
- Establish better commissioning, testing, and validation practices so that as-built / as-operated behavior matches study assumptions.
- Address reliability concerns associated with fault response, automatic load recovery, oscillatory behavior, protection interactions, and power electronic controls.
- Encourage stronger coordination and information exchange between utilities, ISOs/RTOs, developers, manufacturers, and large load operators.
- Reduce the risk of widespread disturbances, instability, or unexpected load tripping caused by rapidly growing and increasingly complex large electronic loads.

## Absence of Uniform National Performance Requirements

While the need to address reliability risks posed by the proliferation of large loads is widely acknowledged, utilities and system operators lack guidance from any uniform national performance standards or requirements for large loads. Uniform performance standards for large loads were not needed in the past because most industrial loads were not very large, there were not very many, and utilities could handle each one on an individual basis. However, the need for detailed technical performance requirements is clear from the high volume of large load interconnection requests, the large project sizes, technological complexity of the emerging large loads, and the already-observed large load disturbance events.

Today, utilities are using different, historically based large load interconnection study methodologies with limited requirements for large load interconnections. This leads to variations in system impact study outcomes, and the

**While the electricity industry has for many years defined a suite of standardized, performance-based technical interconnection requirements for new generators and storage connecting to the grid, no comparable interconnection standards or requirements currently exist for new large loads.**

necessary mitigation of any adverse grid impacts is not always defined or determined correctly. Large load developers are also facing risks in an uncertain regulatory environment, where large load performance requirements, modeling requirements, and study scopes may change during project development.

System reliability can be enhanced through the establishment of interconnection performance requirements for large loads, including:

- **Technical performance requirements** that articulate clear rules for voltage and frequency ride-through, harmonics and flicker limits, power factor ranges, and ramp-rate limits.
- **Protection coordination** that establishes customer-side protection coordinated with the transmission owner's or ISO's protection standards, including anti-islanding and transfer trip where needed.
- **Telemetry and controls** that define the required real-time data (MW/MVAR, voltage, UPS/generator status, curtailment setpoints) to ensure operational awareness and power system control capabilities for the grid operator.
- **Monitoring requirements** that define real-time measurements, including measured signals and measurement resolution and retention policies, for post-commissioning performance analysis and model validation.

Today the technical interconnection requirements for large loads are imposed either on a case-by-case basis or on all load interconnection requests to an individual utility or ISO/RTO. While the electricity industry has for many years defined a suite of standardized, performance-based technical interconnection requirements for new generators and storage connecting to the grid, no comparable interconnection standards or requirements currently exist for new large loads—in part because the growth of new large load demand is so recent that there has been little time to recognize the challenge, identify and study potential solutions, and reach consensus over what specific technical requirements to adopt. For a comprehensive review of the interconnection performance requirements for large load interconnections, see the ESIG Large Loads Task Force report *Large Load Performance Requirements: Current Practices and Recommendations*.[7]

## A Need for More Comprehensive Models and Data to Characterize Large Loads

In many cases, due to lack of clear detailed data and modeling requirements as well as lack of model submission milestones in large loads' interconnection processes, system impact studies for these large load facilities may be based on incomplete or late-arriving information from the load entities. This forces transmission utilities and ISOs/RTOs to rely on potentially inaccurate models and studies based on unknown or inaccurate assumptions on load behavior (e.g., ride-through capability, ramp rates, demand profiles), facility configurations, load compositions (e.g., heating/cooling load versus computational load), and protection and control schemes. The result is that the technical studies yield either overly conservative conclusions regarding the grid impact of the large load interconnection (such as the rejection of the interconnection application or massive transmission upgrades) that impose excessive costs and delays, or overly optimistic projections regarding the grid impact of the large load interconnection (such as interconnection approval without any additional mitigation) that risk compromising system reliability.[8]

To accurately perform interconnection studies that capture large load performance risks, utilities and ISOs/RTOs need significantly more data and detailed load models earlier in the interconnection process from each large load customer. Table 2 (p. 17) describes essential data and model requirements for interconnection technical analyses.

For a comprehensive review of the modeling and data requirements for large load interconnections, see the ESIG Large Loads Task Force report *Large Load Modeling for Dynamic Studies: Current Practices and Recommendations*.[9]

7 See https://www.esig.energy/reports-briefs/large-load-interconnection-performance-requirements/.

8 From ESIG Large Loads Task Force discussions.

9 See https://www.esig.energy/reports-briefs/large-load-modeling.

TABLE 2

## Data and Detailed Load Models Needed by Utilities from Each Large Load Customer

| Data or Model Needed | Description |
|---|---|
| **Load composition data** | Detailed information on load components, such as load type (motor load (heating/cooling), electronic loads, etc.), uninterruptible power supply behavior, and the way they interrelate in shaping the load's overall electricity demand and usage patterns |
| **Load ramp data** | Two types of ramp data: (1) data detailing load ramp schedules, covering the magnitude and speed of anticipated electricity ramping ranging from the millisecond range to seconds, minutes, and hours; and (2) the schedule for how many megawatts of electricity demand per year are expected to be phased into operation over time to accurately evaluate network upgrades and model future dynamic behaviors |
| **PSPD models** | PSPD models that capture the system dynamics in the range of sub-seconds to seconds, to include uninterruptible power supply charge and discharge behavior, rectifier/inverter controls, fast transfer switch behavior, and back-up generators |
| **EMT models** | Simplified, parameterized models sufficient for feasibility-level screening, along with model documentation for converters and uninterruptible power supplies |

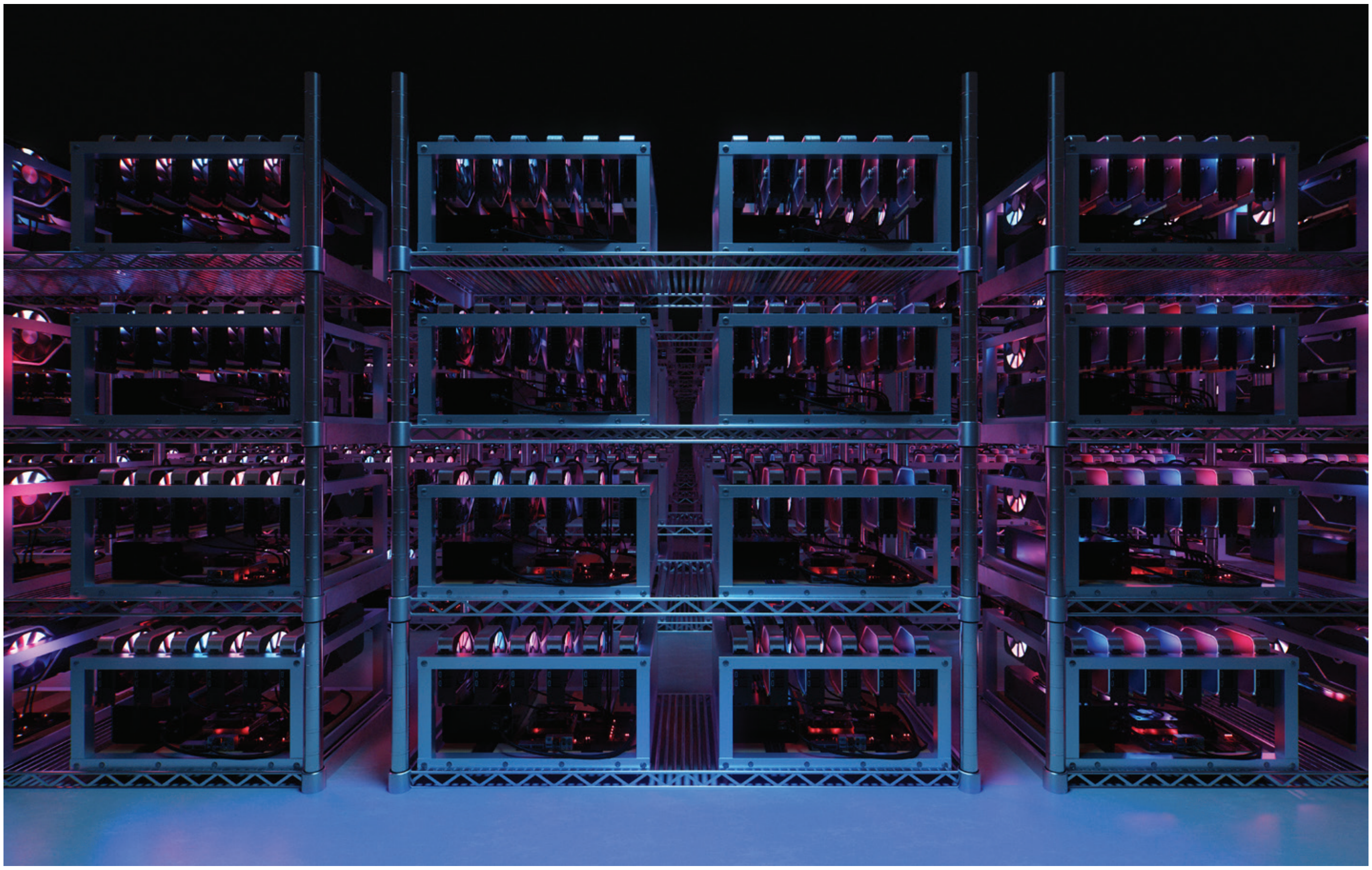
Source: Energy Systems Integration Group.

## Study Requirements for Large Load Impact Assessments

Historically, load studies were generally conducted for each individual new load and focused primarily on steady-state conditions to assess for any thermal and voltage violations and identify network upgrades needed to reliably serve large loads. Dynamic studies for individual new large loads were not of major concern because most loads were resistive heating and motor loads that are long-standing and mature load technologies with well-understood system stability challenges. With the rapid emergence of power electronics–based large loads, study processes must evolve to adequately understand these large load facilities' impact on the bulk power system.

Utilities and ISOs/RTOs are establishing dedicated processes and associated studies (e.g., ERCOT PGRR 115, now codified as ERCOT Planning Guide Section 9 (ERCOT, 2026a)) detailing technical analyses that need to be carried out for large load interconnections. The interconnection process for large loads includes a comprehensive suite of studies to address the unique steady state and dynamic characteristics of today's large load facilities. These studies are:

- **Power flow (steady-state) studies:** This type of study remains foundational and is required to assess for any thermal and voltage violations and identify network upgrades needed to serve the large load reliably under many bulk power system loading, generator dispatch, and contingency conditions.
- **PSPD studies:** These studies are now critical because of the dynamic impacts of large loads, such as the sudden loss of a large load due to lack of ride-through capability, which can create immediate transient stability, voltage, and frequency issues, or slower (below 5 Hz) oscillatory behavior of large loads that can potentially impact overall system stability. PSPD models are used to assess transient stability, small-signal stability, and some of the voltage and frequency ride-through/recovery performance of large loads.
- **Short-circuit studies:** These analyses are performed mainly for the design of protection/control schemes and substation equipment to meet the short-circuit fault duty of circuit breakers, ensuring that grid equipment can withstand and clear maximum fault currents. For large load facilities that have on-site generation, the short-circuit analysis also needs to include



impacts from on-site generation on the bulk power system equipment.

- **EMT studies:** EMT analysis has become crucial due to the oscillatory behavior of AI facilities and dynamic characteristics of crypto currency loads. In particular, AI training loads have been shown to introduce forced sub-synchronous oscillations on the bulk power system, a phenomenon (above 5 Hz) that cannot be accurately represented in steady-state, short-circuit, or PSPD studies.[10] Therefore, EMT studies are now required to accurately model large load rapid ramp phenomena, switching transients, oscillations, and interactions of converter-based controls (UPS/rectifiers).

## Lessons Learned from Large Generation Interconnection

With the rapid rise in large load demand over the past three years, predominantly from data centers and advanced manufacturing, there is an opportunity to apply the lessons learned from IBR integration.

In Order 2003, the Federal Energy Regulatory Commission (FERC) established the Large Generator Interconnection Agreement (LGIA) and Large Generator Interconnection Procedures (LGIP) to address the increasing number of disputes arising from utility and ISO/RTO handling of generator interconnection requests (FERC, 2003). Order 2003 created a standardized framework designed to expedite generator interconnections, establish transparent and non-discriminatory market entry rules for generators, preserve system reliability, and ensure that electricity rates remained just and reasonable for customers.

As demand for new generator interconnections increased, it became clear that the LGIA and LGIP processes needed further modifications. The existing framework was not keeping pace with the volume of interconnection

10 See the ESIG Large Loads Task Force report *Large Load Modeling for Dynamic Studies: Current Practices and Recommendations* at https://www.esig.energy/reports-briefs/large-load-modeling.

requests, especially from IBRs, and FERC was receiving complaints about piecemeal generation interconnection processes that were leading to inconsistent approaches across the country. FERC then adopted Order 2023, which consolidated best practices from individual filings, codified significant process reforms, and established updates to the uniform generation interconnection framework applicable across transmission providers (FERC, 2023a).

FERC Order 2023 revised the *pro forma* generator interconnection procedures and agreements (for both large and small generators) and includes several key reforms, as it:

- Moves from a serial "first-come, first-served" process to a "first-ready, first-served" cluster study approach, in which multiple interconnection requests submitted within the same window are studied as a group rather than individually in serial order.
- Establishes stricter readiness, site control, and financial commitment requirements.
- Imposes firm deadlines and penalties for delayed interconnection studies.
- Requires transparency and sharing of interconnection information between grid operators, utilities, and generator developers.
- Permits co-location of generation and storage resources, evaluates alternative transmission technologies, and clarifies the "option to build" for network upgrades, a provision allowing interconnecting customers to construct certain network upgrades themselves, subject to utility oversight and approval.

National actions to address reliability risks associated with the rapid growth and high levels of IBRs can also serve as a guide for handling large load interconnection requests. In the case of IBRs, NERC and the industry identified reliability gaps between the existing NERC standards, which were mostly designed for synchronous generators, and the new characteristics of IBRs (NERC, 2022). To address these gaps, FERC Order 901, issued in October 2023, mandates the development of new or modified reliability standards to address the integration of IBRs into the nation's bulk power system (FERC, 2023b). NERC is currently in the process of developing new or

**Today, large load interconnection requests, process issues, and undesirable grid events are proliferating at even faster rates than in generation and IBR interconnection, and the industry needs to learn from experience with IBRs and much more rapidly arrive at standardized interconnection processes and performance requirements for large loads.**

modifying reliability standards currently subject to mandatory enforcement pertaining to IBRs in four areas: data sharing, model validation, planning and operational studies, and performance requirements (NERC, 2024).

The ongoing effort to help ensure bulk power system reliability through more streamlined and rigorous IBR interconnection rules and performance requirements highlights how both FERC and NERC processes only slowly identified and resolved the risks inherent in outdated interconnection processes and reliability standards. Today, large loads have begun to show similar issues as seen during the early stage of IBR proliferation like interconnection process confusion and impediments, difficulty accurately studying the interconnecting technology, and power system stability issues. Given the rapid increase in large load facilities and the significant overlap in reliability concerns between large loads and IBRs, industry needs to learn from experience with IBRs and much more rapidly arrive at standardized interconnection processes and performance requirements for large loads.

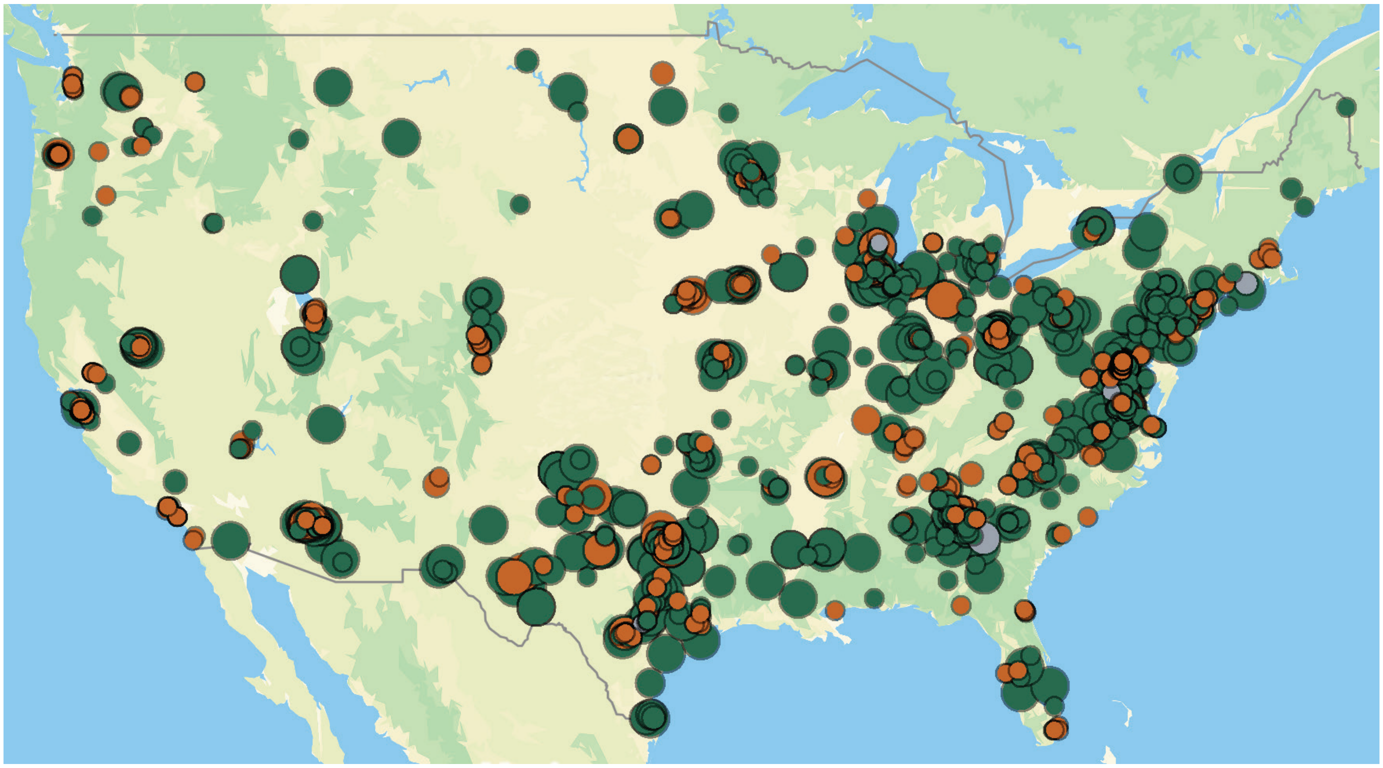
It is essential to formalize clear interconnection processes and performance requirements for large loads to expedite energization timelines while preserving reliability. Even if only a small fraction of the large facilities in interconnection queues are developed, the demand from these large loads may may significantly exceed available supply and transmission capabilities. The large load interconnection process is the starting point for the ISO/RTO or utility to study these new facilities, understand transmission and generation expansion needs, determine whether an expedited interconnection timeline is feasible, and reliably interconnect the large loads.

# Utilities' and ISOs'/RTOs' Current Approaches and the Need for Coordination

Today, as large load interconnection becomes the purview of both utilities and ISOs/RTOs, large load interconnection processes are evolving, with greater coordination required around interconnection requests and data intake, impact studies and study reviews, transmission planning, and resource adequacy assessments. Illustrating the importance of coordination between utilities and ISOs/RTOs, Figure 6 shows the number of data centers operating and proposed across the United States as of 2025, most of which (all but those in the Pacific Northwest) are concentrated in areas served by ISOs and RTOs. In this section we discuss the evolution of current large load interconnection processes and recent proposals and relevant industry/stakeholder

FIGURE 6

**U.S. Data Center Trends**



**This map shows the number of data centers operating (orange)and proposed (green) across the United States as of May 2026, most of which (all but those in the Pacific Northwest) are concentrated in areas served by ISOs and RTOs.**

Note: Marker size reflects capacity. Only facilities with reported capacity data are shown.

Sources: OpenStreetMap and its contributors, posted at Cleanview, https://cleanview.co/public/data-centers/us.

feedback at the ISO/RTO and the utility levels, informed by experiences of the large load owners, operators, and developers in the ESIG Large Loads Task Force.

## Current Interconnection Approaches at Individual Utilities and ISOs/RTOs

### Approaches at Utilities in Non-ISO/RTO Areas

With the proliferation of large loads, utilities are dealing with the same challenges in both ISO/RTO areas and non-ISO/RTO areas, namely, significant impacts to load forecasts, the need for more generation resources, the need for improvements in transmission planning, and others. Utilities faced with rapid growth of large load interconnection requests are already actively working to update their large load interconnection processes to address these challenges. In non-ISO/RTO regions, the utilities continue managing large load interconnections by themselves, as they've done historically. However, as pointed out in Table 1 (p. 12), having all system planning and operation functions contained within one organization (without ISO/RTO oversight) lessens the need for coordination with other parties and, potentially, allows for more nimble evolution of large load interconnection processes. Here we describe examples of recent changes to large load interconnection processes in three non-ISO/RTO utilities.

#### Grant Public Utility District

Grant Public Utility District (Grant PUD) is a customer-owned, non-profit utility in Washington state that has seen enormous large load development in its territory, including data center and manufacturing facilities. The sheer number of large load applications has led Grant PUD to refine its large load interconnection rules, revise its rates, create a formal queue management system, and update its system impact study processes. Grant PUD's transmission interconnection procedures provide a good example of the steps needed to address the explosion of large load interconnections at the utility (Grant PUD, 2023). Its "Transmission Interconnection Procedures" document already echoes many of the recommendations in this report, including having defined interconnection process steps, site control requirements for each customer, large study deposits, detailed study phases, and defined testing and commissioning requirements.

#### Southern Company

In 2025, Southern Company created guidelines in "Integration Process for Transmission Connected Large Loads," and throughout 2025 and 2026 updated this process based on some of the industry guidance and lessons learned (Southern Company, 2026). The utility defines transmission-connected large loads as those loads connected to its transmission system (at greater than 40 kV) and typically those that exceed 50 MW. The integration process has a defined set of five milestones:

- Milestone 1: Commencement of work
- Milestone 2: In-service date (substation ready to feed)
- Milestone 3: Initial energization of transmission-connected large load
- Milestone 4: Testing and verification
- Milestone 5: Full readiness for reliable operations

Southern Company's integration process already aligns with many of the recommendations in this report, including having defined milestones and associated target timelines, defined technical interconnection requirements for large loads, defined modeling data requirements, coordination requirements with transmission operators, and testing and verification of the facility during a defined commissioning process.

#### El Paso Electric

El Paso Electric is another non-ISO/RTO utility that has seen significant growth of large load facilities in its territory, with many large load projects in its interconnection queue (EPE, n.d.). It defines large loads as those exceeding 20 MW and has documented the process steps it takes for connecting large loads to its system. These process steps include defined milestones, interconnection application requirements, significant study deposits, and PSPD studies and EMT studies to thoroughly evaluate each large load facility's impact on its transmission system.

### Approaches at ISOs/RTOs in the U.S.

ISOs and RTOs have started to develop and propose new policies and approaches to handling large load interconnections in their regions to address the challenges of managing load forecasting, resource adequacy assessments, and transmission planning activities under the extreme large load growth requests their regions are seeing.

Several policy initiatives and large load queue management reforms are being discussed across ISOs/RTOs. These initiatives are influenced by stakeholder comments, federal directives, and regional reliability considerations, and many are yet to be finalized. The observations that follow are snapshots of the current approaches and policy directions drawn from the Large Loads Task Force's review as of the time of this writing and may change over time.

### PJM Interconnection

PJM is addressing one of the nation's largest forecasted load increases through its Critical Issue Fast Path (CIFP), an accelerated stakeholder process for urgent matters. The initiative originally centered on a non-capacity backed load (NCBL) service that would allow large loads to interconnect without capacity market backing in exchange for being first to curtail during emergencies, such as during a generation supply shortfall relative to load demand in the region. The NCBL proposal met significant opposition from utilities and consumer advocates centered on concerns that new large loads could obtain grid access without fully contributing to capacity and reliability costs, potentially shifting burdens to existing customers and distorting market signals. Stakeholders also questioned whether emergency curtailment commitments would be sufficiently firm and enforceable, and noted that such loads could still drive transmission upgrades and congestion while receiving preferential treatment through an accelerated policy pathway. As a result of this pushback, PJM is exploring various new policies such as voluntary, incentive-based frameworks, including compensated load flexibility offerings; "bring your own generation" (BYOG) incentives to pair loads with dedicated generation resources; and an expedited interconnection track for state-sponsored generation projects exceeding 500 MW (Mills, 2026).

### Electric Reliability Council of Texas

As of March 2026, ERCOT faced over 410 GW of potential new load from 551 large load interconnection requests—88% of which were from large data centers (ERCOT, 2026c). ERCOT also has 458 GW of new generation and storage interconnection requests, including storage, solar, and natural gas–fired generation (ERCOT, 2026d). For comparison, ERCOT's record peak demand as of this writing is 85.5 GW, set in 2023 (ERCOT, 2026b).

ERCOT has established the most formalized and prescriptive large load interconnection process in the country, shaped directly by Texas Senate Bill 6 (SB 6), passed in 2025.[11] ERCOT's process requires any new or aggregated load at a single site with a peak demand of 75 MW or more to undergo a formal large load interconnection study, analogous to a generator "full interconnection study," including comprehensive steady-state, short-circuit, and dynamic analyses. To combat speculative project application submittals, SB 6 mandates stringent commercial readiness requirements including flat study fees of at least $100,000, proof of site control, and substantial financial commitments for transmission infrastructure construction. The statute empowers ERCOT to require large loads to install equipment for remote disconnection during grid emergencies and mandates inclusion of large loads in the Quarterly Stability Assessment before energization.[12] Implementation details and technical issues continue to be vetted through ERCOT's Large Load Working Group stakeholder process and the Public Utility Commission of Texas.

ERCOT is also working to implement a clustering methodology, called a batch process, to study multiple large load interconnection applications in common geographical and electric topological locations (Ishak, 2026; Billo, 2026). Batch Zero of this new process is expected to start in July 2026.

### Southwest Power Pool

The Southwest Power Pool (SPP) is addressing a potential doubling of its peak load over the next decade through its

11 This was codified by ERCOT through Nodal Protocol Revision Request 1234 (NPRR1234) and Planning Guide Revision Request 115 (PGRR115) (which has now been codified as Section 9 of the ERCOT Planning Guide).

12 The Quarterly Stability Assessment is a study carried out by ERCOT with the goal of assessing stability impacts from all new projects that have met specified interconnection process milestones. Originally, this assessment was introduced to evaluate combined stability impacts from newly connecting IBRs, and, more recently, new large loads have also been included.

High-Impact Large Load (HILL) policy approved by the board of directors. A load is classified as a HILL if it has peak demand greater than or equal to 10 MW at a point of interconnection of 69 kV or less, or peak demand greater than or equal to 50 MW at a point of interconnection above 69 kV. The integrated framework defines interconnection study requirements for applicable new large load interconnection requests, while also having operational requirements that include load forecasting, capability for the transmission operator to remotely disconnect the load from the transmission system, installation of phasor measurement units at large load facilities, and ride-through requirements. This development process serves as a case study in effective stakeholder engagement: after an initial proposal was rejected in July 2025 due to concerns about a rushed process and insufficient review time, SPP staff conducted additional workshops, revised their proposal based on feedback, and achieved 95.7% approval from the Markets and Operations Policy Committee. FERC approved SPP's HILL and High-Impact Large Load Generator Assessment (HILLGA) processes on January 15, 2026 (FERC, 2026a). The cornerstone of the HILLGA approach is an integrated, 90-day study-and-approval process designed specifically for large loads paired with new or existing generation resources.

### New York Independent System Operator

The New York Independent System Operator (NYISO) uses a more established approach to large load interconnection, managing the challenge through its existing tariff and planning manual framework rather than developing entirely new processes (NYISO, 2026). Under NYISO's threshold-based system, any load of 10 MW or greater connecting at 115 kV or above, or any load of 80 MW or greater at sub-115 kV voltages, triggers a formal NYISO-administered system impact study—the sole study required for new loads that meet these criteria, analogous to generation interconnection studies. This study determines whether the load addition would degrade system reliability or affect New York's bulk transmission operations, with results reviewed by NYISO's Operating Committee. If problems are identified, NYISO specifies required system upgrades that the relevant utility evaluates and undertakes in coordination with the load customer, with cost responsibility worked out in an interconnection agreement. Stakeholders have been cautiously optimistic about NYISO's process,

citing the clear threshold criteria that give developers early certainty about study requirements.

Given the relatively small size of the New York grid and the area's extensive interconnections to PJM, ISO New England, and the Independent Electricity System Operator for Ontario, it is likely insufficient to consider the impact of large loads on New York grid alone. Accurate grid impact analysis may require joint evaluation with the Northeast's other grid operators and even the Northeast Power Coordinating Council. The New York State Reliability Council has created a Large Load Working Group to work on these issues (NYSRC, 2026).

### California Independent System Operator

The California Independent System Operator (CAISO) is just beginning its large load activities, including initial proposed technical considerations and requirements for large loads and upcoming discussions with stakeholders (CAISO, 2026; MISO, 2026b).

### Midcontinent Independent System Operator

MISO is also just beginning its large load activities, including initial proposed technical considerations and requirements for large loads, considerations for co-located large loads and generation, and upcoming discussions with stakeholders (MISO, 2026c).

## Interconnection Process Challenges and Regional Responses

The overarching issues for ISOs/RTOs and utilities as they address large load interconnections center around: (1) stand-alone large loads seeking firm transmission service; (2) large loads co-located with new or existing generation resources and any expedited processes for such arrangements; and (3) large loads that seek non-firm transmission service (also known as flexible service or load curtailment), and any expedited processes for such arrangements.

In ISO/RTO regions, an additional challenge is the lack of coordination between ISOs/RTOs and utilities. Since most large load entities submit their interconnection requests directly to the interconnecting utility, the ISOs/RTOs are often not involved in these customer discussions and therefore have little to no awareness of the specifics of each large load customer interconnection until much later in the process when information is provided by the utility. This delay hinders accurate load growth forecasts and has adverse impacts on transmission planning and resource adequacy assessments. While ISOs/RTOs recognize the need for coordination with utilities to conduct joint system impact, transmission planning, and resource adequacy analyses, under newly developing large load interconnection approaches in several regions today the attempts for coordination may result in addition of duplicative steps and interconnection delays. Process improvements are needed through clearly defined assessment steps, specified roles and responsibilities, and continued coordination among all stakeholders. Such improvements are actively underway in both ERCOT and SPP.

The interconnection policies and study procedures vary by region, but many of the planning and operational challenges associated with large load integration are shared across regions. Table 3 summarizes these recurring issues in ISO/RTO regions and provides different stakeholder perspectives on each issue and some of the regional responses being undertaken. This table creates the basis for this report's recommendations that follow. While the table focuses on ISO/RTO regions, many of the challenges are applicable in non-ISO/RTO regions as well.

TABLE 3

### Common Challenges Across ISO/RTO Regions

| Challenge Area | Core Issue | Stakeholder Perspectives | Examples of Regional Responses |
|---|---|---|---|
| **Defined large load interconnection process** | Processes used for large load interconnection historically do not work for the amount of large load interconnection requests and the size of the interconnecting large loads seen today. | Utilities and ISOs/RTOs are overwhelmed with large load interconnection requests and need a systematic way to process them efficiently and without adverse impacts to grid reliability.<br><br>Developers lack clear guidance on process, requirements, milestones, and roles and responsibilities. | ERCOT, PJM, and SPP, in close collaboration with the utilities and others, responded with developing and continuously improving large load interconnection processes in their service territories. |
| **Resource adequacy and reliability risk** | Rapid load growth without commensurate generation and supporting system resources threatens to result in capacity shortfalls and reliability events. | Grid operators are concerned about capacity shortfalls; large loads argue their business model requires rapid energization with high reliability.<br><br>Customers say meeting new large load demand requirements will strain resources built to serve existing customers and raise electricity prices for everyone, even though they are not the cost-causers. | PJM is evaluating several proposals including curtailable service for large loads.<br><br>ERCOT has mandated remote large load curtailment capability under Senate Bill 6.<br><br>NYISO is incorporating load flexibility assumptions into reliability planning.<br><br>SPP is proposing a faster interconnection timeline for load accompanied by new generation capacity. |

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TABLE 3

## Common Challenges Across ISO/RTO Regions CONTINUED

| Challenge Area | Core Issue | Stakeholder Perspectives | Examples of Regional Responses |
|---|---|---|---|
| **Transmission capacity and upgrade timelines** | Load centers lack the transmission to support large incremental demand without significant, lengthy, capital-intensive transmission upgrades.<br><br>Grid operators' need for load curtailment capability and lengthy infrastructure build-out time creates a challenge with large load customers' desires for high uptime and immediate grid service. | Grid operators cite system constraints based on the anticipated large queue.<br><br>Large load developers want near-term energization and a path to scalability with timeline certainty.<br><br>Many individual residents and communities do not want data centers or new transmission built nearby.<br><br>Grid operators view large load curtailment as a critical safety valve to protect grid reliability.<br><br>Large load developers (especially data centers) say they need near-perfect uptime.<br><br>Grid operators also want better and stricter rules for large load curtailment due to impacts on load forecast methodologies, use of transmission, resource adequacy assessment, and market bidding.<br><br>Grid operators desire more operation philosophy details from large loads such as voltage control, protection, and load flexibility to maintain grid reliability and improve load forecasts and operations planning. | Utilities increasingly use intake forms to screen large load requests and perform high-level transmission capacity need estimation to provide early insights into potential available transmission capacity. Examples include Dominion Energy Virginia in PJM.<br><br>PJM offers non-firm and interim transmission service for large loads.<br><br>ERCOT allows interim service contingent upon operational restrictions. Utilities in ERCOT offer service agreements at limited capacity until necessary transmission upgrades are completed.<br><br>Under SPP's HILL process, certain large loads may receive conditional service in constrained areas, with curtailment obligations until transmission upgrades are completed.<br><br>NYISO is exploring grid service offerings from flexible loads for scenarios with insufficient transmission capacity to accommodate the loads with firm transmission service.<br><br>Some large loads are seeking to meet their high reliability needs using their own dedicated generation to supplement grid-supplied power. |
| **Speculative queue clogging** | Interconnection queues can be filled with projects lacking commercial viability, consuming engineering staff time and decreasing the accuracy of load forecasts used in resource adequacy assessments and transmission planning processes. | ISOs/RTOs and utilities report wasted engineering staff time and highly uncertain load growth forecasts.<br><br>Large load developers express frustration with slow interconnection processes and unreliable timelines for energization, even though it is the aggregation of their projects that are slowing and complicating queue management. | ERCOT requires a study fee of more than $100,000, requires proof of site control, has financial security requirements, and collects more information to identify duplicative and speculative projects.<br><br>NYISO requires interconnection deposits and has site control requirements.<br><br>SPP and PJM Include similar project readiness requirements. |

— CONTINUED —

TABLE 3

## Common Challenges Across ISO/RTO Regions CONTINUED

| Challenge Area | Core Issue | Stakeholder Perspectives | Examples of Regional Responses |
|---|---|---|---|
| **Cost allocation and fairness** | Transmission infrastructure upgrade costs for large loads are potentially spread amongst all customers. | Load customers and consumer advocates are concerned about rate increases for all customers.<br><br>Large load developers recognize the need for significant transmission investment and expect cost transparency and reliable upgrade timelines.<br><br>ISOs/RTOs indicate needs for reforms to allocate costs fairly to those entities that are responsible for the cost increases. | SPP assigns direct costs to the cost-causer (load and paired generation).<br><br>ERCOT has fair cost contribution mandates under Senate Bill 6.<br><br>NYISO negotiates cost responsibility in interconnection agreements. |
| **Process transparency and speed** | Large load facility development timelines (measured in months) are misaligned with utility planning and construction cycles for transmission and generation (measured in years). | Developers demand transparency in study assumptions and faster, predictable timelines.<br><br>ISOs/RTOs and utilities need to have transparent interconnection queues, with appropriate information protection, and some are exploring providing hosting capacity maps to indicate points of connection with available transmission capacity and estimated times of connection in every region for even more transparency. | SPP has a defined 90-day integrated study process.<br><br>NYISO has specified clear threshold criteria to provide early certainty.<br><br>ERCOT uses a batch study process that includes clear interconnection process milestones and timelines. |
| **Planning visibility** | ISOs/RTOs lack early awareness of large load interconnection requests because these are submitted directly to utilities. | Information delays prevent effective long-range transmission and resource adequacy planning. ISOs'/RTOs' early involvement in the process is essential to better inform their regional load forecasts. | All regions are working to establish earlier notification and coordination mechanisms between ISOs/RTOs and utilities.<br><br>NYISO established large load application requirements that ensure the ISO is aware of large load interconnections in its region.<br><br>PJM has requirements on sharing load forecast information between the ISO and utilities that help to improve planning visibility into upcoming large load growth.<br><br>ERCOT's batch study process includes one-time intake of all applications into the study cycle, in which large load developers submit applications to respective utilities with ERCOT coordinating, validating assumptions, and performing or overseeing the regional reliability/stability portions of the batch study. This ensures early-stage information sharing between the ISO and utilities. |

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TABLE 3

## Common Challenges Across ISO/RTO Regions CONTINUED

| Challenge Area | Core Issue | Stakeholder Perspectives | Examples of Regional Responses |
|---|---|---|---|
| **Undue discrimination** | Some stakeholders are concerned that new rules unfairly target specific large load customer classes (such as data centers) rather than focusing on all large loads and any operational characteristics that can cause reliability risks to the bulk power system. | The large load industry groups are vigilant against singling out one class of large loads, such as data centers, with new rules. Regulators and existing customers believe cost causation rules justify making new large loads pay for all the costs and risks they are adding to the system, thus they do not consider these rules "undue" discrimination.<br><br>Regulators aim to deliver reliable and cost-efficient power to customers. This includes fair cost allocation, interconnection process, and market design. | MISO is working with its stakeholders under the MISO Large Load Working Group to understand the operational characteristics that pose a reliability risk to the MISO transmission system and is working to create new definitions of facility types that may exhibit these operational characteristics. |
| **Threshold gaming and project sizing** | Developers may strategically structure the size of projects to avoid formal study requirements, creating visibility gaps for utilities and ISOs/RTOs and potential reliability blind spots. | Developers seek to minimize costs and timelines.<br><br>ISOs/RTOs are concerned about aggregated impacts of sub-threshold projects (e.g., distribution-connected large loads, and large loads smaller than the defined thresholds).<br><br>Some ISOs/RTOs are working on new rules for assessing the aggregated impacts of smaller projects. | In NYISO some large load developers are splitting projects into multiple ~35 MW facilities to stay below 80 MW threshold, causing NYISO to reconsider appropriate thresholds. |
| **Modeling, study, and performance requirements** | Due to the size and geographical concentration of large loads, previous modeling and study practices as well as performance requirements are insufficient to ensure system reliability. | Grid operators are experiencing reliability events attributed to large load behaviors. These events are not identified during large load impact studies due to inadequate models.<br><br>Large load developers do not have clear guidance on what requirements their facilities should be designed for and what information needs to be included in the facility models. | ERCOT has developed large load modeling and study requirements and has proposed performance requirements for large loads.<br><br>MISO and SPP are also currently developing modeling, study, and performance requirements for large loads. |
| **Material modification process** | The rapid rate of change in technology (particularly for data centers and AI facilities) is outrunning the utility industry's typical planning cycle and change management and material modification capabilities. | As large loads change their plans, technologies, and equipment, those changes need to be reflected in validated and verified large load models and interconnection dynamic analyses performed by utilities and ISOs/RTOs in order to adequately evaluate how changes in a large load's equipment or behavior impacts the system. | |

Source: Energy Systems Integration Group.

## Interconnection Process Recommendations for Transmission-Connected Large Loads

The regional examples reviewed above show that, while specific processes differ, many large load interconnection challenges are common across jurisdictions, including resource and transmission adequacy assessment challenges, timeline transparency, planning visibility, cost allocation, understanding of project readiness, and others. Drawing on these common themes, the following recommendations from the Large Loads Task Force are intended to improve the efficiency, transparency, and technical robustness of large load interconnection processes across ISO/RTO regions.

**Drawing on common themes across regions, these recommendations aim to improve the efficiency, transparency, and technical robustness of large load interconnection processes across ISO/RTO regions.**

### Establish a Formal Large Load Interconnection Process

Utilities that are faced with increasing large load interconnection requests can establish a formal interconnection process with clearly defined milestones (e.g., adopting milestones illustrated in Figure 3, p. 9) as well as requirements, roles and responsibilities, and timelines for each milestone. In ISO/RTO areas, coordination and information exchange procedures and touchpoints can be established between the utility and ISO/RTO.

### Establish a Formal ISO/RTO-Level Interconnection Request Intake Process

Those ISOs/RTOs working to develop their own large load interconnection process, in addition to the interconnection processes managed by utilities, can work with their member utilities to create a single, mandatory point of entry for all large load interconnection requests above a defined threshold (e.g., 20 to 25 MW) to capture loads with material system impacts. This centralized large load request interconnection intake process would require the submission of an extensive, standardized data package that provides all of the data needed for planning and technical reliability studies at both the utility and the ISO/RTO levels.[13] Having a centralized process will help the ISO/RTO maintain a comprehensive and transparent large load interconnection queue and incorporate the data directly into planning studies, thus addressing the fundamental planning visibility problem. NYISO's threshold-based approach provides a proven model, although careful consideration must be given to setting thresholds at appropriate levels to prevent developers from fragmenting projects into multiple facilities that are individually lower than the threshold. Those ISOs/RTOs not looking to centralize the large load interconnection process can create information-sharing mechanisms for all parties for large load interconnection projects.

### Explore the Development of a FERC Large Load Interconnection Procedure

FERC can develop a *pro forma* Large Load Interconnection Procedure analogous to the Large Generator Interconnection Procedure, replacing the current patchwork of state- and utility-level processes. This standardized procedure could incorporate best practices including the rigor of SPP's multi-stage Load Limited Resource Interconnection Service (LLRIS) process, NYISO's threshold-based study triggers, and an optional accelerated pathway for integrated load-plus-generation projects as pioneered by SPP's HILLGA process, providing certainty and consistency for developers and grid planners alike.

### Enhance Coordination Among Load Interconnection, Generator Interconnection, and Transmission Planning Processes

ISOs/RTOs can establish formal, documented procedures to ensure that data from the large load queue are a timely and integral input to (1) the generator interconnection study process, (2) the long-range transmission planning cycles, and (3) new load planning probabilistic scenarios that consider different rates of successful versus

13 For additional discussion of data needs, see the ESIG Large Loads Task Force report *Grid Integration of Large Loads: Introduction to the Large Loads Task Force, Data Needs, and Flexibility*, https://www.esig.energy/reports-briefs/large-load-task-force-introduction.

unsuccessful large load projects in the queues. This coordination ensures that all three planning functions (generation, transmission, and load forecasting) work from consistent and up-to-date assumptions, thus addressing the timing and information mismatch identified across regions. NYISO's Operating Committee review process and MISO's efforts to coordinate its Transmission Expansion Plan and Definitive Planning Phase offer models for effective coordination mechanisms.

## Adopt Standardized Commercial-Readiness Requirements

To deter speculative projects and ensure efficient use of study resources, ISOs/RTOs can adopt a large load interconnection framework modeled on FERC Order 2023 (for generation) and ERCOT's SB 6, including, at a minimum: (1) requiring proof of 100% site control (land ownership, signed lease agreements, or options to purchase or lease land of sufficient size for the facility); (2) requiring substantial, non-refundable application and study fees as well as credit checks/verifications; (3) escalating financial security requirements for estimated transmission upgrade costs, paid at key interconnection process milestones; and (4) requiring engineering and procurement (E&P) commitments for long-lead items in order to mitigate stranded asset risk and utility rate recovery risk.

Applying these requirements consistently to all large load interconnection customers can prevent threshold avoidance strategies.

## Develop Detailed Modeling, Study, and Performance Requirements

To ensure that the reliability impacts of large loads are adequately assessed, utilities and ISOs/RTOs can establish comprehensive requirements for the types of interconnection studies needed, appropriate large load facility models for each study type, the necessary model benchmarking and validation processes, large load performance, and the processes to evaluate large load facilities' conformity with these requirements during the interconnection process and throughout the lifetime of the facility.[14]

## Establish Material Modification Process

ISOs/RTOs and utilities can work collaboratively with large load customers to establish a process for obtaining adequate information about material modifications that may be happening at the large load facility during the interconnection process and after commissioning. This may include criteria for triggering the material modification process and steps that the process should include, for example, information for the ISO/RTO/utility, provision of updated models (and any model benchmarking, validation, or model quality assessment reports), and criteria for identifying which (if any) studies need to be repeated to ensure that the changes do not adversely impact grid reliability and the facility is still in compliance with applicable performance requirements.

## Develop Standardized, Voluntary Flexibility Products

ISOs/RTOs can work collaboratively with large load customers, particularly data center operators, to design and implement standardized, voluntary demand flexibility products, also referred to as demand response products or non-firm transmission service.[15] These market products will need to provide clear flexibility performance requirements and compensation structures, allowing loads to monetize their flexibility (or buy flexibility from other users on the grid) while contributing to grid reliability. Valuable starting points for this work include NYISO's exploration of grid services from flexible loads and PJM's evolution toward flexibility offerings for large loads (NYISO, 2024; PJM, 2026).

## Transition to Cluster Studies for Large Loads and Integrate Large Load Interconnection into Transmission Planning

As large load queues continue to grow, the traditional serial study approach will become a significant

14 See the ESIG Large Loads Task Force reports *Large Load Performance Requirements: Current Practices and Recommendations* (https://www.esig.energy/reports-briefs/large-load-interconnection-performance-requirements) and *Large Load Modeling for Dynamic Studies: Current Practices and Recommendations* (https://www.esig.energy/reports-briefs/large-load-modeling).

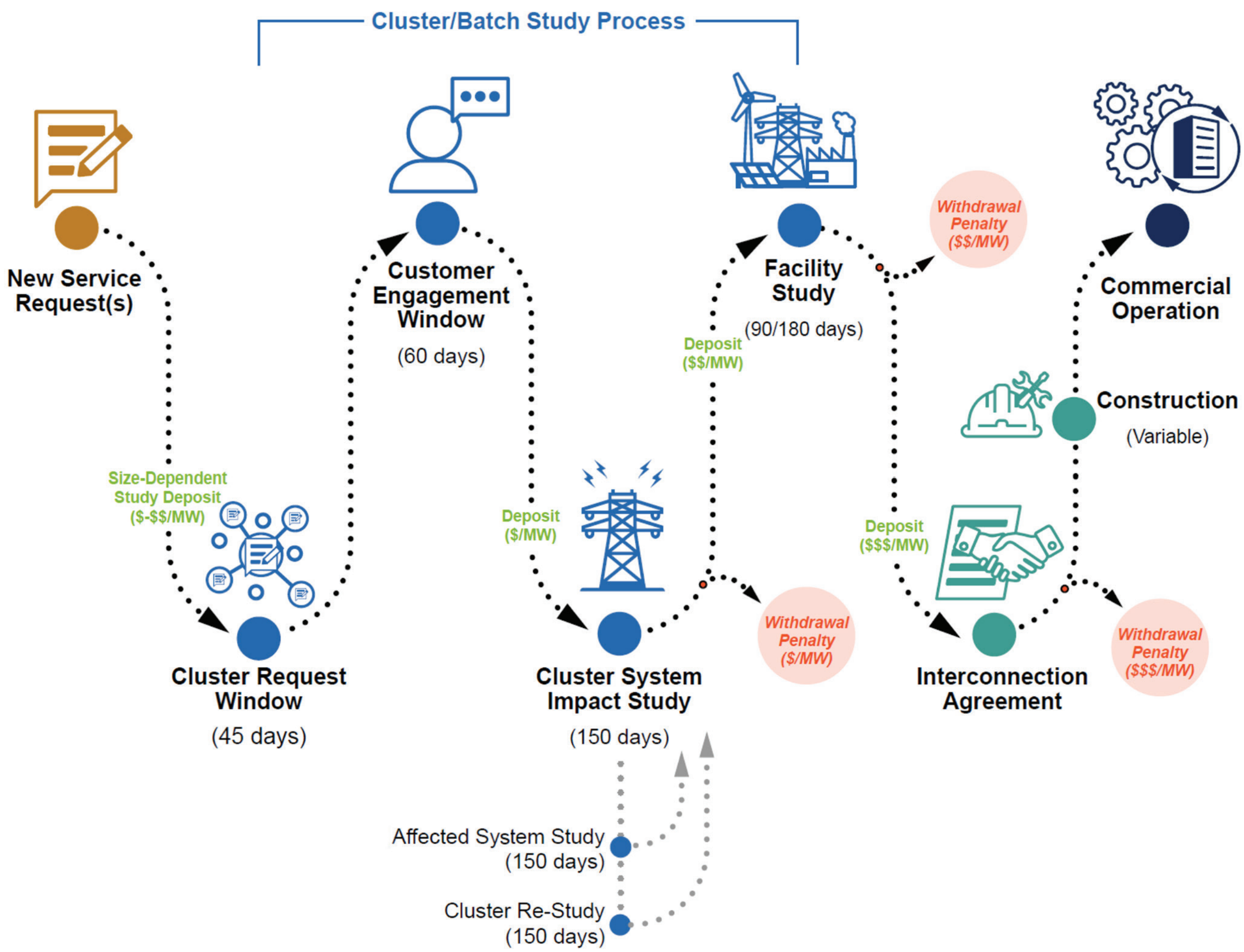
15 For additional discussion of large load flexibility potential and options, see the ESIG Large Loads Task Force report *Grid Integration of Large Loads: Introduction to the Large Loads Task Force, Data Needs, and Flexibility*, https://www.esig.energy/reports-briefs/large-load-task-force-introduction.

bottleneck. Figure 7 illustrates the cluster study process established by FERC for generator interconnection studies under Order 2023. ISOs/RTOs are exploring the use of similar clustering to process multiple large load interconnection requests, potentially in combination with supply resource additions. ISOs/RTOs and the transmission owners can proactively plan for a transition to a cluster study methodology for large loads, incorporating lessons learned from the often-difficult generator queue transitions to cluster studies. For regions with established processes, the transition can be carefully managed to preserve the benefits of existing frameworks while gaining efficiency from cluster approaches. They can also consider performing these cluster studies with not only large load interconnection projects but also generation interconnection projects and planned transmission system upgrade/new build projects as one integrated transmission planning study. This approach is likely to result in more effective transmission system build-outs.

Rules need to be defined that govern how projects are handled when material modifications are made late in the interconnection process and could potentially subject the

FIGURE 7

## Generation Interconnection Procedures as Outlined in FERC Order 2023 Pro-Forma




Source: Joseph Rand et al., *Queued Up: 2024 Edition Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2023*, (Lawrence Berkeley National Laboratory, 2024), https://emp.lbl.gov/sites/default/files/2024-04/Queued%20Up%202024%20Edition_R2.pdf.

project to queue removal and entry into the next cluster study.

## Transmission Capacity Maps and Proactive Transmission Planning

The industry needs to evolve away from the current reactive model of first processing interconnection requests and then planning transmission, and toward a model where long-range transmission planning identifies zones best suited for development, with the interconnection process then prioritizing projects in those zones. CAISO's Interconnection Process Enhancements approach, which aligns generation interconnection requests with planned transmission capacity, represents an example of an important first step that can be refined and adapted for large loads across all regions to improve efficiency and reduce costs by adopting many aspects discussed in this report. This zonal approach would prioritize projects by looking at areas with high transmission capacity, increasing the transparency of the large load interconnection queue or process status for all stakeholders and facilitating efficiencies by reducing backlogs.[16] ERCOT's Competitive Renewable Energy Zones (CREZ) initiative is another landmark example of this type of transmission planning and generation interconnection approach.[17] These can be key examples to consider for large load interconnections.

## Establish Clear Rules for "Bring Your Own Generation" and Co-Located Resources

As the trend of large loads bringing their own generation becomes a common feature of the energy landscape, ISOs/RTOs can develop clear, standardized, and transparent rules governing these hybrid facilities' interconnection process and cost responsibility. The rules should span all milestones of the large load interconnection process to clearly define how a co-located resource is treated, modeled, and studied at each of the interconnection process steps. These rules would help to ensure equitable contribution to system reliability and costs, preventing undue socialization of costs onto other customer classes while maintaining a level playing field for all market participants. SPP's integrated study approach for load-plus-generation projects provides a valuable template for addressing these complex interconnection scenarios.[18]

16 See CAISO's "Interconnection Process Enhancements 5.0" at https://stakeholdercenter.caiso.com/StakeholderInitiatives/Interconnection-process-enhancements-5-0.

17 For more information about ERCOT's CREZ initiative, see https://www.poweruptexas.org/wp-content/uploads/2018/12/Transmission-and-CREZ-Fact-Sheet.pdf.

18 See SPP's one-pager "SPP High Impact Large Load Generator Assessment" at https://www.spp.org/markets-operations/high-impact-large-load-hill-integration/.

# Opportunities for Federal Action on Large Load Interconnection Processes

Much of the recent insight and action on large load interconnections arises from the national experience with the large numbers of large generation interconnection requests over the past decade. Initially, these exceeded utilities' and grid operators' interconnection capabilities and processes and resulted in long, backlogged generation interconnection queues, followed by multiple FERC Orders geared toward alleviating these challenges. Many of the current proposals for how to handle large load interconnection requests mirror the lessons learned from large generation interconnection. Recognizing that similar FERC action with regard to large loads may potentially springboard clearer, streamlined, and harmonized large load interconnection processes, this section zooms in on the current status of FERC efforts and provides recommendations for further evolution toward developing a standardized large load interconnection process.

## Current Status of and Challenges with Defined Large Load Interconnection Processes and Requirements at the National Level

FERC has held technical conferences and proceedings on large loads and co-located generation and load, most notably the Talen case, which highlighted the jurisdictional and practical complexities at issue (FERC, 2024). In October 2025, The U.S. DOE, through Secretary Wright, issued an Advance Notice of Proposed Rulemaking (ANOPR) directing FERC to address reforms intended to ensure the timely and orderly interconnection of large loads to the transmission system (U.S. DOE, 2025b, 1). Since the issuance of the ANOPR in October 2025, FERC has taken several actions related to large load growth. These actions include:

- "Issuing a December 2025 order requiring the PJM Interconnection to implement transparent rules to accommodate substantial loads co-located with generation resources."
- "Approving the Southwest Power Pool's High-Impact Large Load initiative in January 2026, establishing new protocols intended to accelerate the interconnection of large loads and associated new generating resources while safeguarding consumer interests."
- Being "active on multiple proposed tariffs and agreements related to large load interconnections, accepting many, while rejecting those exceeding the Commission's jurisdiction or lacking reasonable cost allocation" (FERC, 2026b).

In addition to these actions, FERC announced in Docket No. RM26-4-000 issued on April 16, 2026, that the Commission intends to act with respect to this docket by the end of June 2026. FERC also stated that in June "we will address the problems discussed in the ANOPR in a manner that is quick, efficient, and legally durable" (FERC, 2026c).

Energy Secretary Wright's letter to FERC cites NERC's concern that "the size and speed with which data centers can be connected to the grid present unique challenges for demand forecasting and system planning" and calls for reforms to make the large load interconnection and cost allocation process efficient, effective, reliable, and fair (U.S. DOE, 2025b, 2). The letter calls for a transparent, orderly, and non-discriminatory process for large load interconnection and lays out 14 principles that can inform FERC rulemaking procedures:

1. Limit FERC's role to within its jurisdiction, namely, the bulk power system

2. Apply a large load process to new loads greater than 20 MW and seek comments on alternative thresholds
3. Study large load and co-located generation interconnection requests together to optimize siting and reduce costs
4. Standardize deposits, readiness, and withdrawal rules to deter speculative projects
5. Base studies of hybrid load/generation facilities on requested injection and withdrawal rights
6. Require protection systems for hybrid facilities
7. Allow faster studies for curtailable or dispatchable loads
8. Make loads fully responsible for network upgrades they trigger
9. Give loads the same "option to build" rights as generators for the interconnecting substation and associated equipment
10. Study any generator suspension (a situation in which a generator reduces its output to the transmission system to send a portion of its electricity directly to a co-located, new large load) like a system support resource or reliability must-run case
11. Base transmission service charges on actual withdrawal rights
12. Tie ancillary service charges to peak demand (no offsets)
13. Define a clear transition plan for large load interconnection studies that defines the timeline and structure for moving from historical large load interconnection studies to new large load interconnection processes/studies (such as moving to cluster studies for large loads)
14. Ensure that utilities serving large loads meet NERC/Open Access Transmission Tariff obligations, and ensure that NERC reviews/updates standards for possible new NERC registration criteria for large load facilities

NERC's focus on large loads has expanded significantly over the past few years in response to the rapid growth of large power electronics–interfaced loads such as data centers, cryptocurrency mining facilities, and other emerging industrial loads. Early efforts included the formation of the Large Loads Task Force under NERC's Reliability and Security Technical Committee to assess the operational, planning, and stability impacts of these facilities and identify gaps in existing reliability frameworks. NERC's task force produced a series of technical reports and recommendations addressing large load characteristics, disturbance behavior, interconnection studies, modeling, and operational visibility (NERC, 2025a; 2026a). Building on this work, NERC convened industry technical conferences and webinars focused on emerging large loads and issued reliability alerts highlighting concerns related to fault ride-through, oscillatory behavior, modeling deficiencies, and load loss events. In 2026, these activities evolved into the Large Loads Working Group and culminated in NERC's Large Loads Action Plan (NERC, 2026e), which outlines a coordinated path forward involving reliability guidelines, standards development, enhanced registration requirements, and improved interconnection, modeling, and operational practices for large loads.

## The European Union's Demand Connection Code: An Example of Harmonized Mandatory Regulation for Loads

An example of how another region has set mandatory, technical rules for large load interconnections can be seen in the European Union's Regulation (EU) 2016/1388 (the Demand Connection Code (DCC)) (EU, 2016).[19] The DCC was drafted by the European Network of Transmission System Operators for Electricity (ENTSO-E) and approved by the European Commission in 2016. The DCC is currently under revision to further adapt it to new challenges brought about by the proliferation of large load facilities, primarily focusing on hydrogen facilities and electric vehicle charging infrastructure. Under the DCC, new transmission-connected load facilities (as well as load facilities on the distribution system and loads that may deliver demand-response services) must meet harmonized technical requirements. The key elements of the European technical requirements for transmission-connected loads are:

19 The term "demand connection" in Europe corresponds to "load interconnection" in the U.S.

- Frequency stability requirements and limits to prevent unnecessary tripping and instability
- Voltage stability requirements including voltage ride-through performance and reactive power support
- Provision of support during system restoration activities, including islanded operation and demand adjustment during blackstart efforts
- Provision of demand response including dynamic power consumption adjustments to respond to frequency and voltage deviations and participation in demand-response events
- Provision of detailed large load facility information with accurate, updated steady-state and dynamic models of the facility
- Applicability primarily to new large load facilities but potentially also to some existing load facilities

Few of the large load requirements defined in the European DCC have been adopted in U.S. regions to date, but it provides a detailed framework that can help the United States accelerate its creation of large load interconnection processes and technical requirements.

## Recommendations

FERC and NERC can move forward expeditiously to consider and act on the U.S. DOE ANOPR, which would address many of the issues highlighted in this report. Additional steps that could be taken by FERC and NERC are the following.

- FERC can consider developing a *pro forma* Large Load Interconnection Agreement (LLIA) and Large Load Interconnection Procedure that cover all of the key issues relevant to large load interconnections including load forecasting, resource adequacy and reliability, interconnection facility design standards, cost responsibility, project schedule, ramp-up period, minimum operation period, large load interconnection queue management, readiness requirements, and interconnection study requirements and timelines. This would require extensive input from the industry (manufacturers of the equipment inside large load facilities, large load developers, owners, operators, and trade organizations; transmission system operators) and NERC.
- NERC can require large loads to register with the Electric Reliability Organization and create large load–specific reliability standards regarding large load modeling, capabilities and performance requirements, physical and cybersecurity requirements, operational requirements, data- and information-sharing, and emergency operation conditions and policies.

# Distribution-Connected Large Load Interconnection Process

Distribution utilities typically consider a load of 10 to 20 MW as a large load that requires special handling (NERC, 2025a). These distribution-connected loads include many common types of facilities the industry has been interconnecting for decades as well as the new types of large load facilities that are the focus of this report (Table 4). In this section, "large load" covers new facilities from 10 to 30 MW rather than the much larger, 1-GW-and-above facilities connecting to utilities discussed up to this point.

Most loads of 10 to 30 MW connect to the grid on a dedicated distribution or sub-transmission circuit. Often distribution-level interconnections give both the utility and the customer greater speed to power and cost less than transmission-level interconnection. The technical scale and differences across load interconnection requirements are summarized in Table 5 (p. 36).

If a 10 or 30 MW load suddenly drops off the distribution system, its effect on the bulk power system is fairly limited

TABLE 4

**Key Characteristics of Common Distribution-Connected Large Load Types (1 to 30 MW)**

| Load Type | Typical MW Range | Key Characteristics |
|---|---|---|
| **Small enterprise data centers** | 1 to 5 MW | Servers, computing equipment, electrical switchgear, and cooling systems, all with a need for high redundancy, high power quality, and 24/7 operation |
| **Large enterprise data centers** | 5 to 30 MW | Servers, computing equipment, electrical switchgear, and cooling systems, with continuous load, back-up generation, and strict uptime requirements |
| **Automotive manufacturing** | 10 to 25 MW | Large motors, welding equipment, and robotics with high short-circuit contribution to the grid |
| **Steel mini-mills** | 20 to 30 MW | Arc furnaces with fluctuating load and high reactive power demand |
| **Semiconductor fabrication plants** | 10 to 30 MW | Precision equipment and clean rooms (highly controlled production environments to eliminate contaminates and particles) with constant load profiles |
| **Cement plants** | 15 to 30 MW | Kilns and grinding mills with continuous heavy-duty operation |
| **Water/wastewater treatment plants** | 5 to 20 MW | Large pumps with seasonal variability and motor starting impact |
| **Medical/research campuses** | 1 to 15 MW | Imaging equipment and laboratories with back-up power requirements |

Source: Energy Systems Integration Group.

TABLE 5

## Differences Between Transmission- and Distribution-Level Large Load Interconnections

| Aspect | Transmission | Sub-Transmission | Distribution |
|---|---|---|---|
| **Voltage level*** | 69 kV or higher | 34.5 to 69 kV | 4 to 34.5 kV |
| **Load size** | Usually 20 MW or larger industrial facilities | Approximately 10 to 30 MW and includes large industrial plants, data centers, and other large regional loads | Typically less than 10 MW; often commercial, institutional, or light industrial loads |
| **Modeling approach** | Uses regional network models and considers inter-area effects | Uses local network models | Uses feeder-level models and focuses on local constraints |
| **Responsibility for upgrades** | Transmission owner or independent system operator coordinates cost allocation | Utility may require customer-funded upgrades on local circuits | Utility may require customer-funded upgrades on local circuits |

* These are not standard voltage definitions but are intended to provide general examples of voltage cut-offs between these parts of the electricity grid.

Source: Energy Systems Integration Group.

compared to the loss of a 1,000 MW data center dropping off the transmission system; however, the distribution-connected load can cause significant local operational reliability problems. Moreover, when many "small" large loads drop simultaneously due to a common cause (as with a fleet of electronically coupled air conditioners triggered by a local transmission fault), their aggregate effect on system voltage and frequency can be significant. Therefore, most distribution-level large load technical interconnection processes, requirements, and studies need to be consistent with transmission-level large load interconnection processes, requirements, and studies.

In addition, new interconnection approaches such as "bridging interconnections" are emerging to address the mismatch between rapid facility development timelines and the longer timelines required for transmission upgrades. Under this approach, a large load initially interconnects at the distribution or sub-transmission level to support early phases of facility operation and load ramp-up, while permanent transmission infrastructure is being developed. This evolving interconnection model highlights the increasing need for coordination among utilities, transmission owners, and ISOs/RTOs, particularly as load facilities expand from modest initial demand to hundreds of megawatts over time and ultimately transition to direct transmission service.

## Current Status and Challenges

Distribution interconnections generally fall under state jurisdiction, managed by public utility commissions or local utilities without direct FERC oversight. This allows for more utility-specific rules that can attract large load developers with facilities in the 1 to 30 MW range; however, this can lead to process and reliability inconsistencies across regions. For example, the boundary between transmission and distribution is not always clear; sub-transmission may blur the lines and is sometimes treated as part of the bulk power system if it impacts reliability. Therefore, it is important to coordinate across stakeholders to avoid inconsistent, reliability-compromising treatment of large loads interconnected at distribution or sub-transmission levels.

Large loads interconnecting at the distribution level may have shorter timelines to interconnect than transmission interconnections due to fewer queue backlogs or detailed

**It is important to coordinate across stakeholders to avoid inconsistent, reliability-compromising treatment of large loads interconnected at distribution or sub-transmission levels.**

studies, fewer permitting requirements, or a lower likelihood of a need for new major distribution infrastructure such as substations or lines.

A large load interconnection request on a utility distribution network typically begins with the customer submitting an interconnection or new service application with high-level technical details such as site address and location coordinates, anticipated load size (kW or MW), voltage level, and type of service (e.g., single-phase or three-phase). Additional details often include the desired in-service date, construction schedule, load shape, and desired load service (continuous or intermittent). Customers must also provide load characteristics, such as peak demand, power factor, and any special equipment that could affect power quality. For large or complex loads, utilities may request one-line diagrams, equipment specifications, operational characteristics, and protection/control settings. Typically, models of large load facilities are not required, but that may need to change in time due to the new operational characteristics of new large power electronics–based loads that can have important grid impacts.

So while transmission interconnection studies focus on assessing the impact of the new load on bulk power system reliability, distribution interconnection studies evaluate the impact of the new customer on local feeders, nearby customers, transformers, and voltage regulation to ensure safe and reliable distribution service.

Withdrawal capacity maps (a new term for load hosting capacity maps) show where the system has enough capacity to host additional large customers; they can be used to attract load developers to specific locations and thus shorten analysis time and uncertainty. These withdrawal capacity maps are interactive tools that show the grid's ability to accommodate additional demand such as electric vehicle fleet charging, data centers, or industrial facilities without compromising distribution asset loading, local power quality, or reliability. Unlike generation-focused hosting capacity maps, which indicate how many more distributed energy resources (DERs) such as solar photovoltaic systems can be added in specific places on the grid, load hosting capacity maps emphasize available capacity for new loads. They incorporate data on circuits, feeders, and substations; peak load conditions; and system voltage levels to inform interconnection decisions.

By providing geospatial data on available capacity, publicly available maps facilitate more informed decision-making for interconnecting new loads. These maps provide transparency and allow developers, regulators, and end users to assess distribution system capacity initially without having to consult the utility. This enables stakeholders to identify opportunities for load additions, supports efficient site selection, and helps to ensure project viability. Developers can direct efforts toward locations with ample capacity, thus minimizing the risk of rejection during the formal interconnection application. In addition, load hosting capacity maps can aid utilities in identifying constraints that may warrant proactive upgrades, as well as support integrated resource planning efforts and flexible interconnections.

## Distribution-Connected Large Loads and Distributed Energy Resources

Regulated electric utilities have an obligation to serve customers' demand, but that obligation is not unconditional. The customer's facility must connect to the distribution grid in a safe and reliable manner and not pose a threat to the grid and the other customers it serves. However, the high volatility and unpredictability of large loads can introduce distribution system risks such as rapid power flow fluctuations, voltage and frequency deviations, harmonics, and potential cascading failures. These necessitate imposing significant technical requirements and protections upon distribution-connected large load customers as a condition of electricity service, to protect the grid and other customers.

### Utility Technical Requirements to Ensure a Reliable Distribution System

A utility's establishment of technical requirements and protections for large loads is similar in process and necessity to what utilities have implemented for the interconnection and operational requirements for DERs. Utility requirements for DERs are designed to ensure that customer-owned generation, such as solar photovoltaics, batteries, or small wind systems, can safely operate in parallel with the utility grid. These requirements include technical standards (IEEE 1547 for voltage and frequency, and protection coordination), interconnection studies to evaluate the grid impacts (voltage rise, voltage fluc-tuations, fault current contribution, protection, thermal loading, harmonics, and flicker), and operational protocols such as communication, control, and metering to enable monitoring and dispatch coordination. The utility's role is to assess these impacts and define any necessary upgrades or protection settings before granting permission to operate.

Most large loads want highly reliable electricity service. To manage the risk of service interruptions and outages, many large loads are building back-up generation and storage behind the meter to ensure operational continuity. This means that many large load customers also seek to interconnect large DER installations at the same interconnection point (whether behind the meter or at the point of interconnection feeding into the utility distribution system). Traditional loads prioritize unidirectional supply reliability, but new large loads mirror DER challenges by needing bidirectional considerations for power quality and system protection impacts.

Distribution-level grid protection requirements for large loads (akin to the IEEE 1547 DER interconnection standard) need to include:

1. **Detailed interconnection studies and modeling:** Mandates for comprehensive assessments covering power flow, ramp rates, load operational behavior, and protection settings
2. **Performance criteria:** Performance requirements for large load voltage and frequency ride-through, power factor maintenance, power quality compliance, and ramp-rate limits (short term (to mitigate spikes from AI training) and long term (load size ramp up))
3. **Monitoring and data sharing:** Requirements for fault/disturbance recording and power quality monitoring for real-time visibility,[20] and mandatory sharing of forecasts or operational changes
4. **Protection and coordination:** Coordination of facility protection (e.g., UPS and parallel or back-up generation) with utility systems and enabling of demand response for curtailment during contingencies
5. **Operational and enforcement measures:** Contracts with minimum load factors, utility rights for inspections, corrective action or disconnection for non-compliance, and ensuring equitable cost allocation

## New Types of Interconnection: Flexible, Bridging, and Others

One way to speed up and simplify the interconnection process for large loads is flexible interconnection. This approach allows large loads and DERs to connect to the grid under conditional arrangements rather than wait for all traditional upgrades to be completed (CHARGED, 2026). Instead of delaying projects until full distribution system capacity is available, utilities and customers agree on operating limits—such as phased energization, temporary capacity caps, or curtailment during peak demand conditions—while permanent upgrades are planned and executed. This method often uses real-time monitoring, advanced controls, and grid-enhancing technologies such as dynamic line rating, topology optimization software, and advanced power flow control devices to manage reliability risks. The result is faster project realization timelines, better use of existing infrastructure, and improved economic development opportunities, all while maintaining system stability and safety.

Due to the limited size of the load able to interconnect at the distribution level (dictated by the voltage level) and the complex and extended timeline of transmission interconnection process, new types of load interconnection configurations, like bridging interconnections, are surfacing. As mentioned above, a bridging interconnection allows a smaller large load to temporarily connect at a medium-voltage distribution level or a sub-transmission level while permanent transmission infrastructure is constructed and loads ramp up, eventually switching to a direct transmission tie. This approach is increasingly being considered for high-demand loads like data centers, where the build timeline outpaces the grid upgrades necessary. Many large loads ramp up from a few megawatts to hundreds of megawatts over several years (SCE, 2024; EPRI, 2024; Dominion Energy, 2024). The early phases of the facility ramp-up process could be served by local feeders. Some utilities are using this process to expedite the interconnection of new, mid-sized loads and start partial operations before the full transmission grid capacity is ready.

20 Some utilities require Power Quality meters to ensure sufficient resolution of fault recording, while supervisory control and data acquisition (SCADA)/advanced metering infrastructure (AMI) is used for real-time visibility.

The bridging interconnection process poses many complexities and risks, which highlight the need for coordinated distribution and transmission planning for such transitions. The bridging interconnection process requires clear load ramp-up and ramp-down agreements via temporary service agreements defining load caps, duration, upgrade cost recovery, and terms governing the load's eventual transition to the transmission system. Additionally, parallel load interconnection processes to the transmission system must be in place, requiring developers to maintain queue position for their permanent transmission interconnection. Detailed, granular load monitoring is needed to ensure the interconnection terms are not violated and distribution system reliability is not compromised. The regulatory complexity across state (public utility commission) and federal (FERC) jurisdictions must be navigated to ensure a proper transition between distribution to transmission, which requires precise planning and coordination. Lastly, there is a risk that the temporary facilities used to connect the new large load to the distribution system could be stranded or decommissioned once the load connects at the transmission level. There needs to be an explicit plan to repurpose temporary facilities for back-up, emergency feed, or future load expansion in the region.

### Cost Allocation

Utilities allocate the cost of infrastructure upgrades through a combination of rate recovery mechanisms, interconnection agreements, and regulatory approved tariffs, guided by the principles of cost causation to ensure that those responsible for driving the need bear a proportional share. When demand growth occurs organically, through existing and gradual growth in residential, commercial, or small industrial customers, utilities typically forecast load-driven distribution infrastructure needs and recover upgrade costs (as for substation expansion, feeders, or lines) through broad-based retail rates approved by public utility commissions. This approach spreads expenses across all ratepayers in the form of high base rates or surcharges, reflecting the embedded cost of service where historical and projected system-wide investment are amortized over time. But with the surge in demand from new large loads like data centers, electric vehicle fleets, and manufacturing facilities, some utilities are adapting existing practices to isolate incremental costs, conducting detailed interconnection studies to identify upgrades required (such as new transformers, voltage support devices, or transmission reinforcement), and allocating those costs directly to the new user to avoid raising the cost burden on existing customers.

## Interconnection Process Recommendations for Distribution-Connected Large Loads

As stated above, while distribution-connected large loads are much smaller than those connected to the transmission or sub-transmission systems, it is important to ensure that processes for distribution-connected large loads are clearly structured and establish formal coordination, data-sharing, and performance requirements. Given that today's large loads are predominantly power electronics–connected, there is an increased risk for multiple facilities to disconnect from the grid during similar grid conditions. This, combined with the total size of these distribution-connected large loads in the aggregate, means the process for these large loads must be thorough and ensure that what is connected represents what has been studied.

### Establish Structured Interconnection Process

As distribution-connected large loads continue to grow in size and complexity, utilities will need more structured and transparent interconnection processes with clearly defined application requirements, study procedures, milestones, and timelines. Distribution-level studies increasingly need to evaluate dynamic load behavior, power quality, protection coordination, and interactions with behind-the-meter generation and storage. Additional modeling and operational data requirements may also be necessary.

### Establish Formal Coordination Between Distribution and Transmission Planning

Closer coordination between distribution and transmission planning functions will become increasingly important, as some distribution-connected large loads can materially affect sub-transmission and bulk power system operations. Utilities can establish formal information-sharing and coordination mechanisms, particularly for facilities expected to ramp significantly over time or transition from distribution to transmission service through bridging interconnection arrangements.

## Develop Withdrawal Capacity Maps and Flexible Interconnection Approaches

Expanded use of publicly available withdrawal capacity maps (i.e., hosting capacity maps) and other pre-application screening tools can improve transparency, guide developers toward areas with available capacity, and reduce study uncertainty. Utilities can also continue exploring flexible interconnection approaches, including non-firm, provisional, and bridging service options, to accelerate interconnections where firm service is not immediately available.

## Develop Distribution-Level Technical Requirements for Large Loads

Utilities, regulators, and industry organizations can consider developing more harmonized technical and performance requirements for distribution-connected large loads, similar in concept to requirements applied to DERs. These requirements may include voltage and frequency ride-through, power quality, monitoring and telemetry, disturbance recording, communications capabilities, and protection coordination requirements needed to support reliable system operation.

# Conclusions and Recommendations

The rapid growth of large load interconnection requests, driven primarily by data centers and AI, marks a structural shift in how the electric power system must plan for and accommodate new demand. Without proactive reform, existing interconnection processes risk slowing economic growth, creating reliability challenges, and raising costs for all customers. Some of these challenges are analogous to those of the generation interconnection process. The electricity industry has a unique opportunity today to rapidly apply the lessons learned from generation interconnection reform to large load interconnection before these challenges become widespread.

**The electricity industry has a unique opportunity today to rapidly apply the lessons learned from generation interconnection reform to large load interconnection before the challenges become widespread.**

Large load interconnections can be more efficient, reliable, and faster by establishing a harmonized, transparent, and milestone-based interconnection framework spanning utilities, ISOs/RTOs, and federal and state regulators. Fragmented approaches will not scale to meet the magnitude of anticipated load growth. A coordinated response among utilities, ISOs/RTOs, large load owners and operators, and regulators is necessary—one that balances economic development with system reliability, cost protection for existing customers, and efficient infrastructure deployment.

These conclusions align closely with the U.S. DOE's ANOPR on large loads, which emphasizes the need for improved visibility into large load development, consistent interconnection practices, and proactive planning for high-impact demand (U.S. DOE, 2025b). Key principles proposed by DOE supported in this report include enhanced data collection and transparency for large load projects, improved load forecasting, interconnection process and planning coordination, clear cost responsibility frameworks, integration of demand flexibility and on-site generation, and explicit reliability considerations for high-density load growth.

The report's recommendations, intended to create a more harmonized, transparent, and efficient interconnection framework for large loads, are summarized below. They are based on the Large Loads Task Force's review of current practices and challenges and draw from the experience and expertise of task force participants including system operators, utilities, data center operators, regulators, and researchers. The recommendations aim to preserve latitude for regional and local variation while establishing the consistency and rigor that large load integration demands. Figure 8 (p. 44) illustrates of how other key recommendations align with the recommended milestone-based large load interconnection process.

## Large Load Interconnection Process Overall

- The entities that are responsible for large load interconnection processes can follow the recommendations in this report to create more uniform, transparent interconnection processes across the U.S. that will help improve efficiency and speed of large load interconnections. It is recommended that the process be based on clearly defined milestones with readiness requirements that provide credible indication of project viability, roles and responsibilities, timelines, and cost allocation frameworks.

- The potential for development of a FERC Large Load Interconnection Procedure can be explored that establishes a baseline framework for large load interconnection under FERC jurisdiction, analogous to existing generation interconnection procedures, with transparent processes, defined milestones, timelines, and cost responsibility frameworks. States and non-FERC jurisdictional entities could consider adapting the LLIP for large load interconnections over which they have authority.
- The large load interconnection application packages, site control (land ownership, signed lease agreements, or options to purchase or lease land of sufficient size for the facility), and financial readiness requirements can be applied to filter speculative interconnection requests and reduce queue congestion driven by large load projects that lack the commitment to proceed. Harmonizing these requirements insofar as possible across the nation will further help to improve the clarity and efficiency of the large load interconnection process.
- Consistent financial security requirements can be implemented across all interconnection providers, including milestone payments and withdrawal penalties, to mitigate the risk of stranded infrastructure investment and ensure appropriate utility cost recovery from large loads.
- Material modification rules can be finalized to maintain the integrity of interconnection queues and study processes as project configurations evolve, balancing the need to accommodate technological change with the need to preserve study integrity and planning assumptions.
- Expanded use of hosting capacity maps early in the siting and interconnection process can guide large load developers toward locations with available grid capacity, reducing initial study complexity and queue processing time.

## Large Load Interconnection Process Coordination

- Coordination among utilities and ISOs/RTOs needs to be enhanced throughout the interconnection process, including formal information-sharing protocols and joint study procedures for facilities that interact with multiple grid layers.
- Queue transparency can be improved at both utilities and ISOs/RTOs, including harmonized treatment of duplicate requests and consistent application of interconnection requirements across service territories.
- Large load interconnections can be integrated into regional transmission planning processes, ensuring that the infrastructure needs of large load growth are reflected in long-term planning and cost allocation frameworks.

## Large Load Interconnection Process Studies

- When the volume of large load connection requests exceeds a preset level, utilities and ISOs/RTOs can transition to cluster study approaches for large loads, consistent with reforms already underway for generator interconnection. This approach improves study efficiency and reduces the compounding delays created by serial study queues.
- For every large load interconnection, steady-state, PSPD, and short-circuit studies need to be performed that meet applicable NERC, ISO/RTO, and utility study requirements.
- A screening process can be established to determine when certain large load facilities require EMT studies and those studies performed for the large load facilities identified.
- Harmonized reliability study methods can be developed for studying co-located load and generation, including conditions under which they are studied as a single entity.

## Large Load Interconnection Technical Requirements

- Clear performance and capability requirements for large loads can be developed that apply for the lifetime of these facilities. These include detailed technical modeling requirements for PSPD and EMT models that would be submitted as a part of the interconnection application and updated throughout the interconnection process as facility design and construction advances.[21]
- Technical requirements and practices for assessing loads' conformity with the requirements can be unified across the U.S. grid to enable efficiency and consistency for all large load interconnections.
- NERC large load–specific reliability standards can be developed that address load modeling, performance and capability requirements, physical and cybersecurity, operational coordination, data sharing, emergency operating conditions, and other reliability topic areas. NERC has already started work to develop an interim set of requirements for large loads, to be followed by a more comprehensive applicable standards revisions effort.
- NERC can create an additional registration category that would specify which large loads would be subject to mandatory enforceable requirements within its regulatory area. This separation of large loads in the compliance space can allow for the more efficient creation of technology-specific requirements that will help enhance bulk power system reliability without overburdening traditional large loads (e.g., industrial loads such as steel and glass production) or creating insufficient requirements that fit all large load types. NERC has already begun the work of creating and defining this large load registered entity.

## New Solutions to Speed Up Large Load Interconnection

- Harmonized voluntary flexibility products can be developed, including provisional, surplus, and non-firm service options, to give large load customers more flexibility options and accelerate interconnection where firm service is not immediately available.[22]
- Clear, consistent rules can be established for bring-your-own-generation arrangements and generation resources co-located with large loads. The rules will need to clearly define how a co-located resource is treated, modeled, and studied at each of the large load interconnection process milestones.

## Staffing Resources

- Utilities and ISOs/RTOs need sufficient staffing resources to process the growing volume and complexity of large load interconnection requests.

Figure 8 (p. 44) shows the alignment of the report's recommendations with the seven milestones of the large load interconnection process. Taken together, these recommendations provide a practical and technically grounded pathway toward a large load interconnection framework that supports the reliable, efficient, and timely integration of large load facilities into the U.S. electric power system.

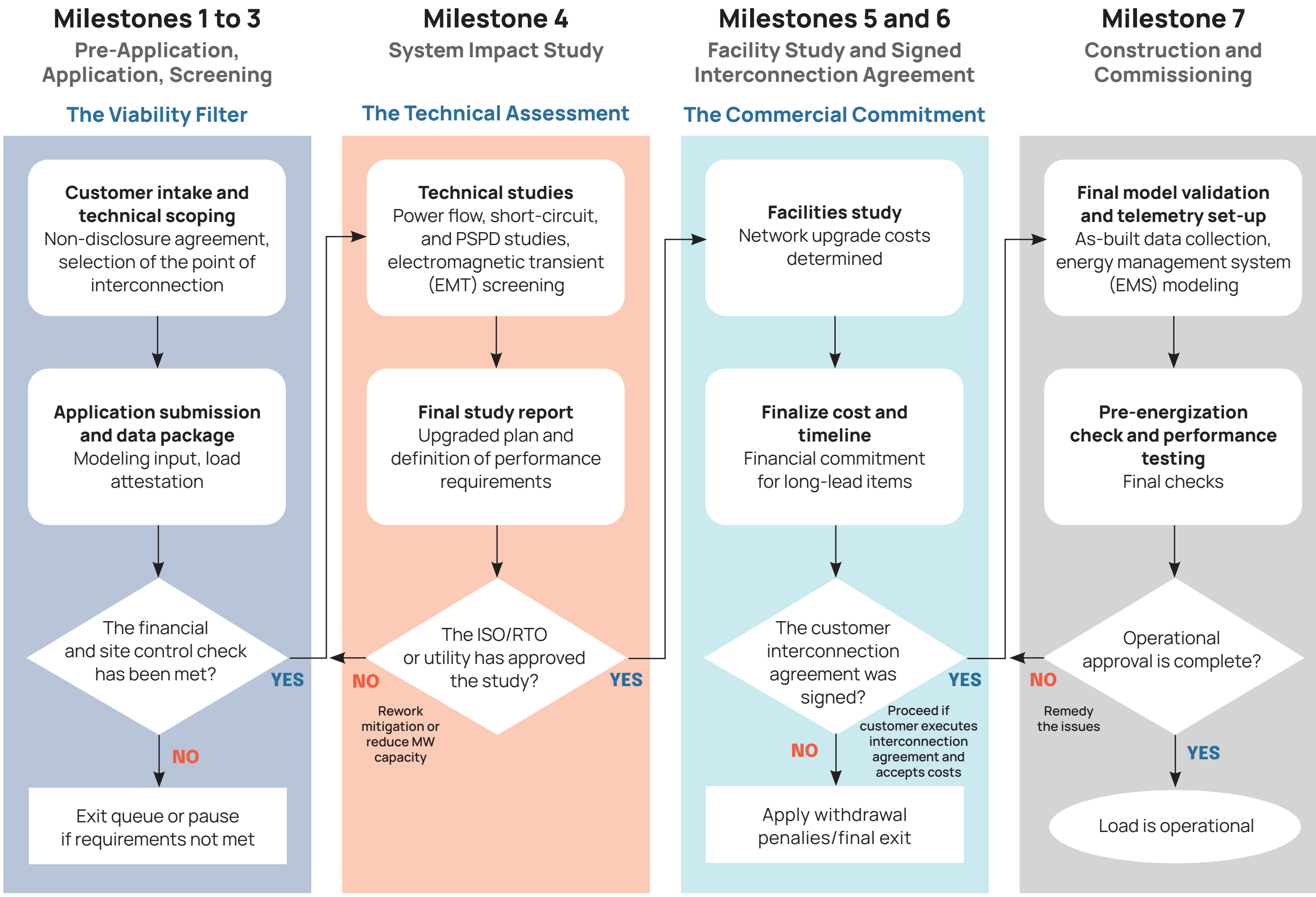
**Taken together, these recommendations provide a practical and technically grounded pathway toward a large load interconnection framework that supports the reliable, efficient, and timely integration of large load facilities into the U.S. electric power system.**

21 See the ESIG Large Loads Task Force reports *Large Load Modeling for Dynamic Studies: Current Practices and Recommendations* (https://www.esig.energy/reports-briefs/large-load-modeling) and Large Load Performance Requirements: Current Practices and Recommendations (https://www.esig.energy/reports-briefs/large-load-interconnection-performance-requirements).

22 For a longer discussion of large load flexibility, see the ESIG Large Loads Task Force report *Grid Integration of Large Loads: Introduction to the Large Loads Task Force, Data Needs, and Flexibility* (https://www.esig.energy/reports-briefs/large-load-task-force-introduction).

FIGURE 8

## The Recommended Large Load Interconnection Process Presented in This Report




### KEY RECOMMENDATIONS

- Implement standardized application packages and financial readiness criteria to filter speculative interconnection requests
- Establish centralized ISO/RTO-level interconnection request intake
- Use hosting capacity maps early to guide siting and reduce initial study complexity

- Develop consistent technical requirements for load modeling (e.g., PSPD, EMT), types of studies to be carried out, and interconnection requirements
- Establish study requirements for co-located generation
- Ensure adequate resources (i.e., staffing and tools) at ISOs/RTOs and utilities

- Standardize financial commitment requirements to mitigate stranded asset and utility rate recovery risks
- Establish a material modification process including triggers, model update requirements, and re-study criteria

- Establish requirements for model validation and conformity assessment with applicable performance requirements

Note: Each step may include nuances depending on the utility type.

- Implement a transparent large load interconnection process with clearly defined milestones, roles and responsibilities, and timelines for each milestone

- Establish clear rules and requirements for cluster studies, flexibility product provision, and "bring your own generation" considerations

**Large load interconnections are a primary driver of grid investment and operational risk, and without standardized processes, the industry will face escalating delays; potential cost-shifting from large loads to other, existing customers; and significant reliability risks. Proactive implementation of standardized large load interconnection processes, grounded in both the lessons of generation interconnection reform and the U.S. Department of Energy's emerging policy framework, offers the most effective path forward for accommodating rapid load growth while protecting the public interest and preserving the reliability of the electric power system. This figure gives a high-level overview of the recommended large load interconnection process presented in this report.**

Source: Energy Systems Integration Group.

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# Interconnection Processes for Large Loads: Current Practices and Recommendations

**A Report by the**
**Energy Systems Integration Group's**
**Large Loads Task Force**

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The report is available at https://www.esig.energy/resources/reports-and-briefs/.

To learn more about ESIG's work on this topic, please send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. More information is available at https://www.esig.energy.

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