Visualization and Analysis of United States Independent System Operator Generator Interconnection Requests

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***Abstract*—This paper explores the process of consolidating interconnection queue data from seven Independent System Operators (ISOs), CAISO, SPP, PJM, ERCOT, ISO-NE, NYISO, and MISO, into a comprehensive and unified database for use in power systems research. The goal is to create a single, large-scale dataset that captures all interconnection requests across these ISOs, facilitating in-depth analysis of trends in generation capacity seeking to connect to the U.S. grid. This unified database enables the visualization of the evolving energy mix within these requests, assesses potential impacts on the US transmission network, and supports informed decision making on future investments in the regions governed by these ISOs. In addition to merging these data sources, this paper details the data cleaning and processing steps necessary to ensure the resulting data set is accurate, reliable, and actionable for stakeholders in grid planning, energy policy, and infrastructure development.**

***Index Terms*—Independent System Operators (ISOs), Generator Interconnection Queues, Transmission Planning, Transmission Network Impact, Renewable Energy Integration, Energy Source Trends**

I. Introduction

GENERATOR interconnection queues, maintained by Independent System Operators (ISOs), catalog new generation projects seeking to participate in ISO energy markets. Each project must pass a series of technical studies that gauge its feasibility and potential grid impacts; the standard process and timeline are detailed in [1]. As non-profit entities charged with operating their regions' power grids, ISOs also administer these studies and the broader interconnection process. Yet because each ISO structures and labels its queue differently, cross-regional analyses become cumbersome, hindering data-driven transmission planning. This paper demonstrates how consolidating the queues from seven U.S. ISOs into a unified, standardized dataset can unlock richer insights and support smarter infrastructure investment.

The ISOs of interest in this study are CAISO [2], ERCOT [3], ISO-NE [4], MISO [5], NYISO [6], PJM [7], and SPP [8]. Each ISO maintains and publishes an interconnection queue containing data on generators seeking to interconnect with the grid. Key data points within these queues include generator capacity, fuel type, project status, proposed location (state and county), interconnection request date, proposed commercial operation date, interconnection point, and associated transmission voltage, among others. However, the content and format of these interconnection queues are not standardized across the ISOs. Each ISO captures different sets of information, and even when similar data are included, they may be labeled differently. This lack of standardization complicates cross-ISO data analysis without first developing a consistent naming convention and identifying the relevant data for integration into a unified database.

To address this challenge, we developed a standardized database by collating and standardizing interconnection queue data from the seven ISOs into a single, comprehensive dataset. This unified database can be leveraged for various analyses. It will enable the visualization of trends in renewable energy growth, help assess the percentage of queued projects that ultimately proceed to construction, and allow for the estimation of potential added generation capacity on an annual basis. Furthermore, the data can be used to create power system planning models, which can test the current grid infrastructure's ability to accommodate the added generation and identify the need for system expansion to support future capacity. As discussed in [9], the power grid must continuously expand its generation capacity to meet growing consumer demand, and carefully assessing the impact of each new generator interconnection is crucial to this process [9].

This research contributes to the growing effort to integrate renewable energy sources into the grid while ensuring that the infrastructure can handle future demand. By utilizing the compiled database of interconnection data, this paper demonstrates how research planning models can simulate various scenarios, allowing stakeholders to predict whether

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specific entries will pass the system impact study and move on to construction. Ultimately, this work helps inform policymakers, grid operators, and investors, aiding them in making more informed decisions regarding grid expansion and the integration of new generation resources into the US power grid.

II. Methodology

A. Obtaining the Interconnection Queue Data

There are two primary methods for obtaining generator interconnection queue data from each ISO: manual download and automated API querying. The manual method involves navigating each ISO's official website to locate and download the interconnection queues, typically available in formats such as .csv, .xlsx, or occasionally .xml. The second, more efficient approach involves leveraging APIs to query the ISOs' interconnection queue data. This method allows for automation through scripting in languages such as Python, utilizing libraries like requests [10] and pandas [11] to fetch, parse, and store data directly into a structured format for analysis. For greater efficiency, we employed the "gridstatus" Python library [12], which facilitates querying interconnection queue data across multiple ISOs. This library streamlines the querying process by simplifying commands and performing preliminary data cleaning, reducing the effort required in subsequent steps. The API method provides a more scalable solution for handling large datasets and automating the unification of interconnection queue information across the various ISOs.

B. Data Cleaning and Standardization

The interconnection queue datasets from different ISOs exhibit significant variation in format, content, and naming conventions. These inconsistencies must be addressed to allow for effective analysis. For instance, the same data points may be labeled differently across ISOs (e.g., "Queue Date" vs. "Interconnection Request Receive Date"). Identifying such discrepancies and normalizing the naming conventions is crucial to avoid redundancy and ensure proper integration of data from various sources. The cleaning process involves first manually reviewing the downloaded data to identify common categories and their respective inconsistencies. Next, columns are consolidated and renamed to ensure uniformity. This step is vital for reducing data redundancy and aligning similar data points, which simplifies subsequent analyses. The resulting standardized dataset is essential for creating a unified interconnection queue database, which will be used for trend analysis, visualization, and future grid planning.

C. Data Preparation for PowerWorld Integration

Following the cleaning and consolidation of the interconnection queue data, the dataset is further processed to be compatible with PowerWorld, a widely used tool for power system modeling and simulation. The interconnection queue data is reformatted to resemble the structure of the EIA 860 database, which is proven to meet PowerWorld's requirements [13]. One challenge in preparing the data for PowerWorld is the lack of precise geospatial information for planned generation projects. As the interconnection queues only provide state and county-level information, coordinates for each project must be estimated. This is achieved by using the geographic coordinates of the county centroids or, where available, by referencing project-specific reports that provide location details. These estimated coordinates are added as placeholders for latitude and longitude. With the addition of geographic coordinates, the dataset is then suitable for creating a power system planning case in PowerWorld using the approach outlined in [14]. This case allows for the simulation of grid performance under various scenarios, enabling the assessment of the grid's ability to integrate new generation capacity and the identification of areas requiring infrastructure expansion. While the present work focuses on the visualization and organization of interconnection queue data, the application of this dataset in PowerWorld for detailed grid performance analysis represents a subsequent, forward-looking step of this research.

III. Visualization and analysis of interconnection data

Following the cleaning and standardization of the interconnection queue dataset, the data was prepared for analysis and visualization. To facilitate a comprehensive review and enhance clarity, the analysis was conducted using Python, specifically leveraging the Matplotlib [14] library for data visualization. The interconnection queue dataset comprises over two decades of information detailing the status of interconnection requests—categorized as active, completed, or withdrawn. For this study, a sample period spanning from January 2014 to December 2024 was selected, covering the most recent eleven years of data. Within this period, the annual distribution of interconnection requests was extracted, and the status of each request was categorized accordingly. The results are presented in Fig. 1, illustrating both the volume and status of interconnection requests as of May 2025.

As illustrated in Fig. 1, a total of 451 interconnection requests were submitted in 2014. Of these, only 102 had reached completion as of May 2025, while the majority—322 requests—were withdrawn, and 27 remained active in the queue. Analyzing the annual trends within the selected sample period reveals a significant year-over-year increase in interconnection requests from 2014 through 2021. However, beginning in 2022, the number of new interconnection requests began to decline. A similar trend is observed in the number of withdrawn requests during this period. Notably, as of May 2025, only eight requests out of the total submitted since January 2021 have reached completion. This observation provides a practical indication of the typical time required for an interconnection request to transition from submission to completion.

Using the same sample period, we analyzed the interconnection queue dataset to assess the annual addition of generation capacity (in gigawatts, GW) from projects marked as complete. The regions managed by ERCOT and CAISO were excluded

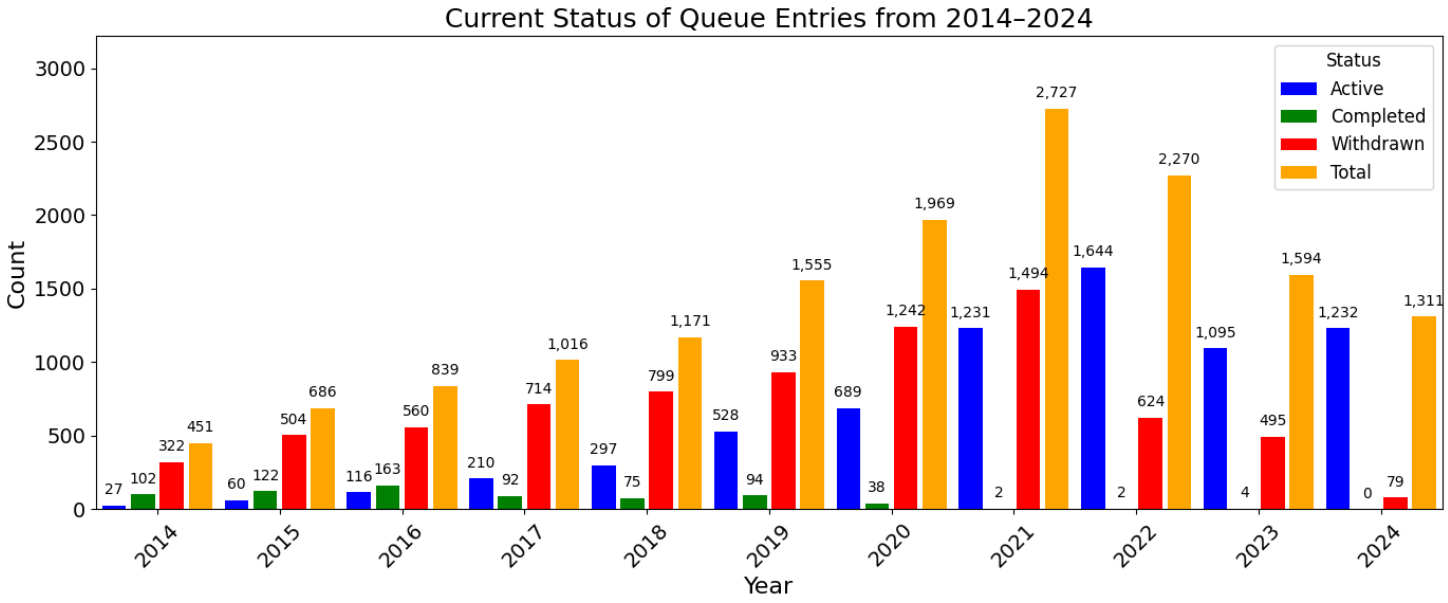

Fig. 1. Current Status of Queue Entries from January 2014 to December 2024.

from this analysis due to the unavailability of corresponding completion data. As illustrated in Fig. 2, the total generation capacity added by completed projects peaked in 2018, reaching approximately 18.2 GW, the highest annual addition observed between 2014 and 2024. Conversely, 2024 recorded the lowest completed capacity, totaling only 6.9 GW. Across the observed period, the average annual generation capacity added to the grid from completed interconnection requests is approximately 10 GW.

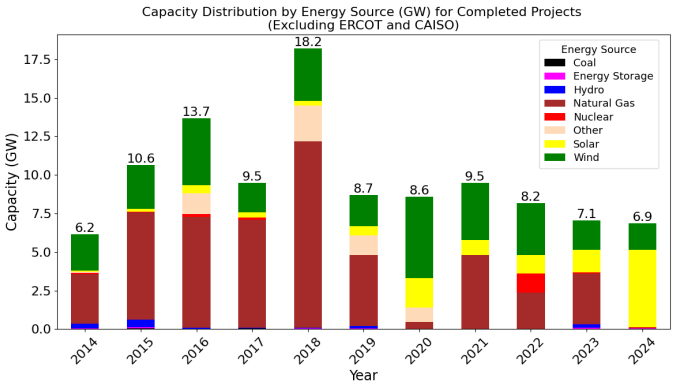

Fig. 2. Capacity Distribution by Energy Source (GW) for Completed Projects (Excluding ERCOT and CAISO).

Disaggregation of the annual capacity of completed generator interconnection requests into its constituent technologies—solar photovoltaic (PV), wind, natural gas, coal, nuclear, battery energy storage systems (BESS), and others—enables the extraction of technology-specific deployment trends that are indispensable for transmission system planning. Fig. 2 presents the technology-specific breakdown of the added capacity of the completed generator interconnection requests each year (Excluding ERCOT and CAISO).

As shown in Fig. 2, the annual capacity distribution of completed generator interconnection projects by technology reveals a pronounced decline in the commissioning of new nuclear and coal units over the 2014–2024 period. Notwithstanding this trend, a 2022 upgrade project augmented the capacity of an existing nuclear facility by approximately 1 GW. Over the full sample period, natural gas–fired plants dominated completions, with wind ranking second, while solar PV exhibited a steady upward trajectory. In 2024, solar PV achieved its highest annual share of completed projects—exceeding 70% of the total—followed by wind at roughly 25%, with all other technologies contributing the remaining 5%. Preliminary data for January–May 2025 indicate that solar, wind, and energy storage interconnections constituted approximately 90%, 5%, and 5%, respectively, of completed projects in the first five months of 2025. Although drawing firm conclusions from last year's completed interconnection requests alone may be premature, examining active requests slated for future commissioning is likely to confirm the shift toward renewable generation. Should high renewable penetration prevail, significant adaptations—such as enhanced fast-ramping capabilities, synthetic inertia controls, and revised protection settings—will be required to maintain system stability and reliability in a transmission-constrained grid [15].

To frame the subsequent analysis of active requests by capacity and technology, it is essential to first quantify project life-cycle dynamics by comparing annual completions with the year-end backlog. Fig. 3 illustrates, for each calendar year, the number of interconnection requests that achieved completion

versus those that remained active and rolled over into the next period. This dual-metric visualization highlights the throughput of the queue, exposes processing bottlenecks, and informs transmission planners of emerging workload trends that may affect scheduling, resource allocation, and system reliability assessments.

Fig. 3 illustrates an exponential growth in annual interconnection request submissions since 2018, while completion throughput has remained constrained. Indeed, the proportion of year-end active requests that transition to completion in the subsequent year has declined steadily from approximately 12% in 2018 to near 2% in 2023. Without substantive procedural enhancements, this disparity will drive a continuously expanding backlog. As of 31 December 2024, 7,474 requests remain active across the seven ISOs, underscoring the urgent need for streamlined interconnection review and processing protocols. Although a large proportion of proposed capacity may ultimately not materialize, rigorous analysis of the active queue—encompassing both total proposed capacity and technology mix—remains essential to substantiate and plan for the accelerating transition to renewable generation.

Considering the active interconnection requests in aggregate, we can forecast the prospective annual capacity additions predicated on each project's planned in-service date. While historical attrition rates demonstrate that only a fraction of proposed capacity ultimately achieves commercial operation, the observed long-term average annual addition—on the order of 10 GW (excluding ERCOT and CAISO)-provides a pragmatic realization ratio for forecasting. Accordingly, Fig. 4 depicts the anticipated annual capacity to be added for currently active projects under their stipulated in-service dates: a "full build-out" scenario assuming 100% completion.

Analysis of the active entries in the interconnection queue indicates that most projects are slated for commercial operation between 2025 and 2028, with anticipated annual capacity additions exceeding 100 GW each year from 2026 to 2028 and 90.3 GW expected between May and December 2025. The observed decline in anticipated capacity additions beyond 2028 is likely attributable to the finite scope of currently active interconnection queue entries, which predominantly target commercial operation dates within the 2025–2028 window. This temporal concentration reflects typical project development horizons, as most developers provide projected in-service dates within a 3–5 year time frame from their queue entry. Consequently, the sharp reduction in capacity additions in 2029 and beyond does not necessarily imply a slowdown in long-term deployment but rather indicates that most queued projects are expected to be completed by 2028, with fewer projects currently scheduled for later years due to inherent uncertainties in longer-term project planning and permitting timelines.

Fig. 4 presents the technology breakdown of these active requests, revealing a dominant share of solar PV, energy storage, and wind alongside smaller proportions of natural gas, and other resources. With this data we then went on the analyze the constituent technology across these active projects.

Analysis of the constituent technology across active interconnection requests slated for 2025-2028 reveals a pronounced emphasis on inverter-based resources, with battery energy storage systems and solar PV dominating the proposed capacity. Specifically, energy storage projects account for approximately 20% of the total planned additions, solar PV contributes 50%, wind represents 15%, natural gas–fired plants make up 7%, and all other technologies comprise the remaining 8%. This capacity mix highlights the grid's evolving resource portfolio—characterized by high flexibility and variability from storage and renewables—while underscoring the continued reliance on thermal generation for firm capacity and system inertia. The detailed energy-source distribution not only quantifies the accelerating penetration of renewables but also supplies transmission planners with the necessary inputs for scenario-based power-flow analyses, reserve margin calculations, and network expansion studies to ensure system reliability under evolving generation portfolios.

To refine our projections, we next examined the annual technology mix of withdrawn interconnection requests. While active projects indicate emerging resource trends and completed projects reflect historically realized capacity, incorporating withdrawal data provides a more rigorous basis for estimating, by technology, which active proposals are most likely to advance to commercial operation. By quantifying withdrawals by technology, we can derive empirical "survival rates" for each resource type—thereby adjusting fore-casted build-out volumes to account for attrition. Fig. 5 depicts the number of withdrawn projects per year, disaggregated by energy source, for the 2014–2024 sample period. This comparative analysis of completion, activation, and withdrawal trends yields a clearer picture of the net capacity that may ultimately materialize by technology, informing more robust transmission planning and reliability assessments.

As illustrated in Fig. 5, battery energy storage systems (BESS) constitute the largest share of annual withdrawals throughout the 2014–2024 period, which corresponds to their negligible contribution to historically completed capacity. Solar photovoltaic (PV) projects account for the second-highest withdrawal volumes, explaining the modest solar completions prior to 2020; although solar completion rates have since increased, withdrawal levels remain elevated, indicating that a substantial fraction of planned solar capacity may still be deferred or canceled. Wind projects rank third in withdrawal volumes, exhibiting relatively modest withdrawal counts and only a slight decline in completion rates from 2014 to 2023. However, the marked surge in withdrawn wind projects in 2024 portends a further deterioration in their anticipated completion ratios. Natural gas shows a declining withdrawal trend over time, reflecting improved delivery of gas-fired capacity. All other technologies exhibit low withdrawal counts, commensurate with their smaller share of interconnection activity. By integrating these withdrawal patterns with active and completed project data, planners can derive technology-specific attrition rates to refine forecasts of net capacity build-out.

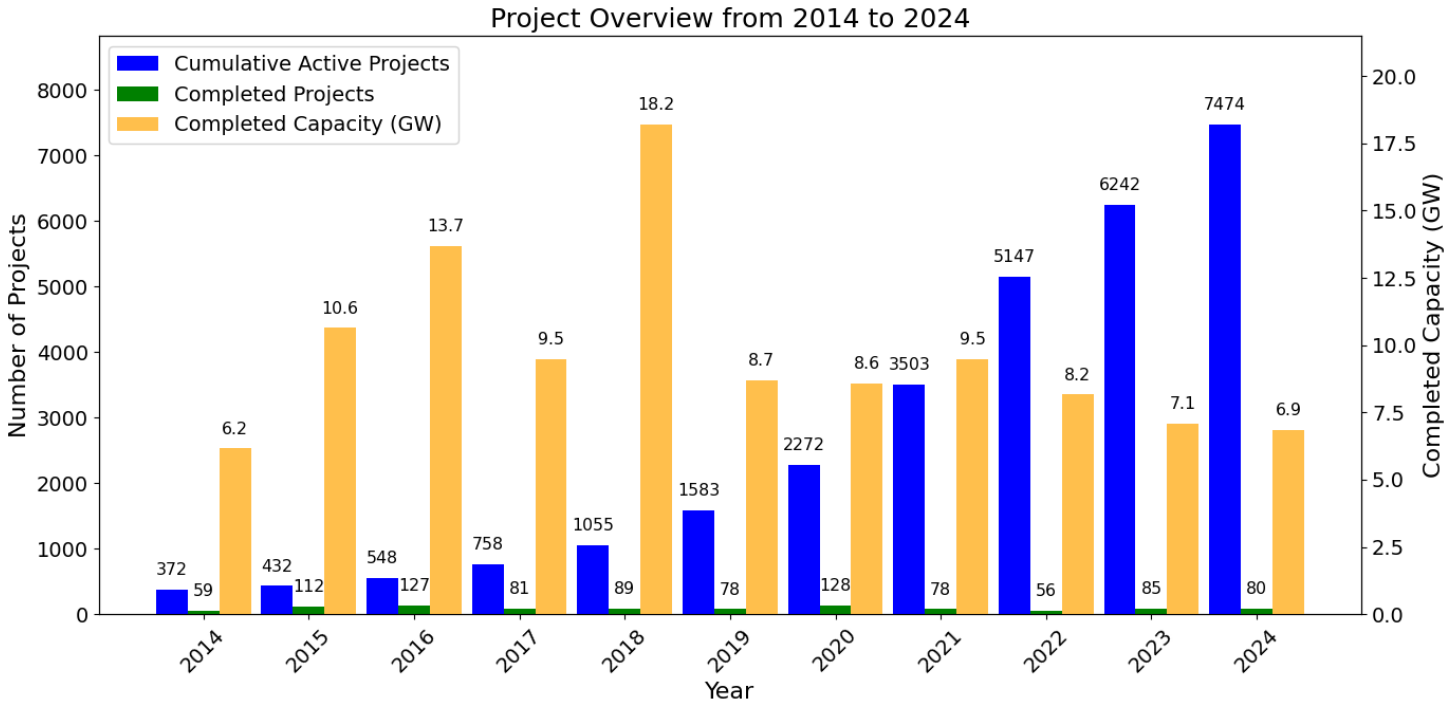

Fig. 3. Project Overview from January 2014 to December 2024.

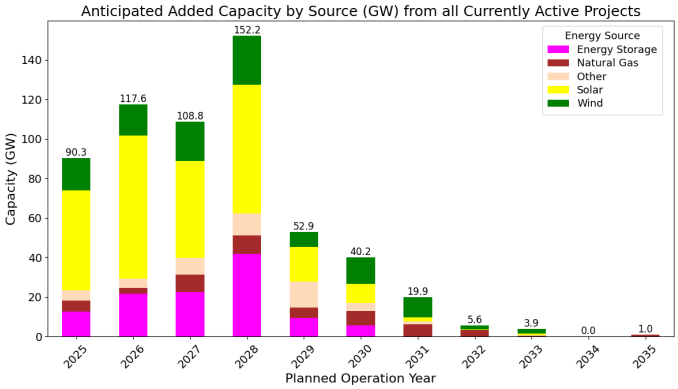

Fig. 4. Anticipated Added Capacity by Source (GW) from all Currently Active Projects per Planned Operation Year.

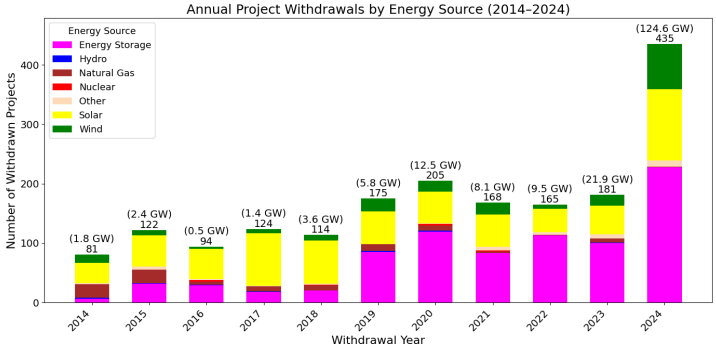

Fig. 5. Annual Project Withdrawals by Energy Source (2014–2024).

To further support transmission planning, we quantified the queue-to-operation lead time by analyzing all completed interconnection requests in the unified dataset. For each project, we recorded the calendar year of queue entry and the date of commercial operation, then computed the mean, median, and mode of the resulting durations. Fig. 6 presents the empirical distribution of these lead times, revealing the central tendency and spread of project development cycles.

As shown in Fig. 6, the mode of the queue-to-operation lead-time distribution is approximately one year, indicating that the largest single cohort of projects completes within 12 months. However, the median lead time is 4.0 years, and the mean interval is 3.78 years, reflecting a right-skewed distribution and underscoring the prevalence of multi-year development cycles for generator interconnection projects. This statistical characterization enables planners to set realistic expectations for project delivery, anticipate throughput delays, and align network reinforcement schedules with probable commissioning horizons.

IV. Conclusion

This paper presents a comprehensive methodology for unifying the generator interconnection queues from all seven U.S. Independent System Operators (ISOs) into a consolidated dataset. This unified queue database serves as a critical tool to support more coherent transmission planning and informed

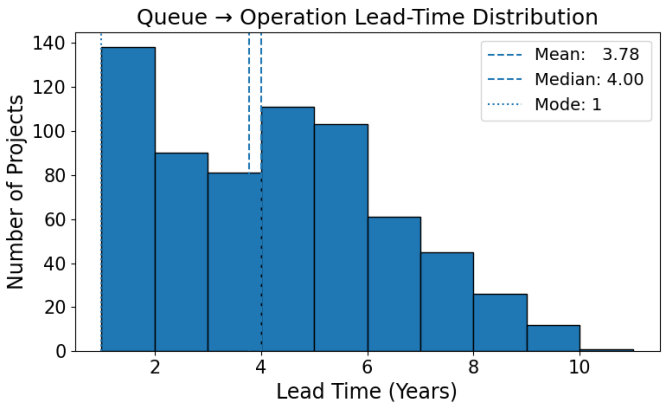

Fig. 6. Queue to Operation Lead-Time Distribution.

energy investment decisions across the United States. Building on this foundation, we further developed a large-scale power system planning case in PowerWorld that incorporates all active entries in the interconnection queues, providing a system-wide view of potential future generation capacity additions and their implications.

We conducted an in-depth analysis and visualization of the generation interconnection queues to characterize historical and projected trends. Our findings indicate that the majority of proposed new capacity is concentrated in wind, solar, and energy storage resources, consistent with national decarbonization targets and market evolution. Project completion timelines exhibit significant delays, with commercial operation dates typically lagging initial projections by 2–4 years. The total volume of projects in the interconnection queues expanded by approximately 50% annually between 2018 and 2022, and has continued to grow at a rate of about 25% per year since 2022. However, despite this rapid increase in queued capacity, the number of projects successfully reaching commercial operation has remained relatively constant each year. Only approximately 15-20% of proposed projects in the queues ultimately achieve commercial operation, highlighting the high attrition rates inherent in the interconnection process.

These insights underscore the pressing need to enhance interconnection queue management practices. Streamlined analytical approaches that rapidly screen out technically or economically infeasible projects—combined with early, transparent estimates of transmission system upgrade costs—can empower developers to make informed decisions and reduce queue congestion. Such improvements are essential to ensure that interconnection queues more accurately reflect viable near-term generation capacity and to facilitate timely transmission expansion aligned with the nation's evolving energy landscape.

A subsequent study will provide a comprehensive overview of the PowerWorld planning case constructed from this dataset, and will detail the range of analyses that can inform transmission-expansion strategies and energy-investment decisions.

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