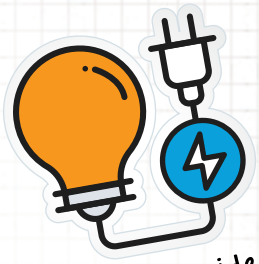
PJM's Advanced Technology Initiative



Watch a video.

The initiative:

Provides opportunities for innovators — including PJM staff, member organizations, research and academic institutions, and industry experts — to advance power grid operations and wholesale electricity markets

Builds on PJM's history of innovation and reflects its commitment to community collaboration and enhancing the reliability and cost-effectiveness of the bulk power system

Supports innovation in-house, in partnerships and through its Advanced Technology Pilot Program

Select a topic to explore.

Data Centers

Storage and Hybrids

Virtual Power Plants

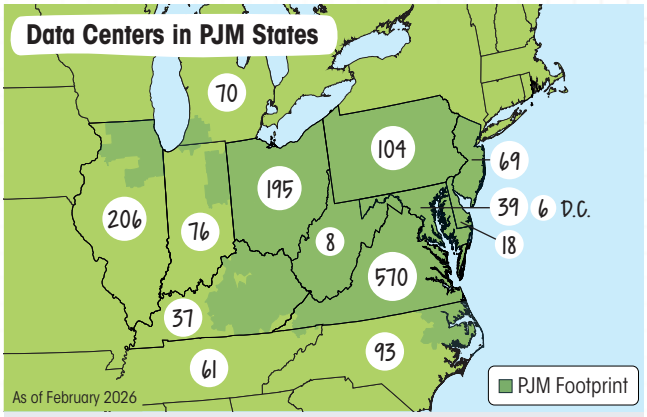
Electric Vehicles

Topology Control

Advanced Conductors

Data Centers and Load Flexibility

Powering the current and projected rapid increase in data center electrical demand is an issue having profound impacts across the power sector.

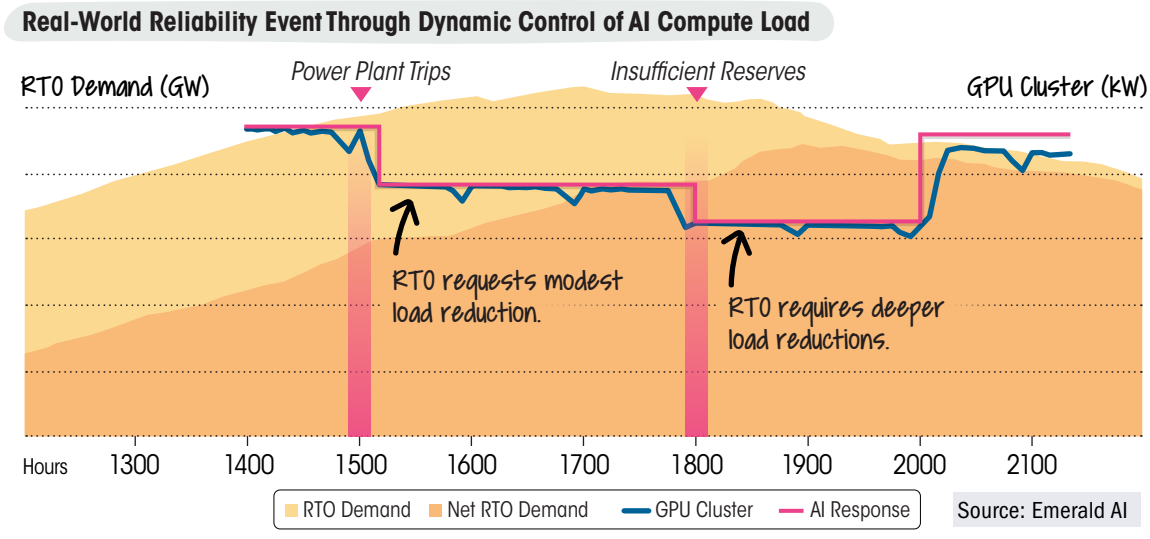


Source: https://www.datacentermap.com/usa

Stakeholders around the country, and particularly in the PJM region, are focused on maintaining reliability using various technology and policy solutions to accommodate the demand for cloud services, cryptocurrency, artificial intelligence and other needs of the information economy that are driving growth in large load data center facilities. In addition to the importance of building new generation and transmission to meet this demand growth, data centers themselves can serve as a solution to help grid operators meet demand, especially during the most critical peak hours of the year. To serve in this capacity, data centers can be designed with their own level of load flexibility to be able to respond to signals from grid operators that the system is in need of additional support. Those could be price-based signals or emergency communications.

Data centers and many other large load customers often have emergency backup generation that can sometimes be utilized to reduce a customer's load during emergency conditions. Data centers may also be designed in the future with cleaner generation sources at the same site that can run much more often and when the grid is not in an emergency. These are important capabilities and data center integration strategies.

Through an industry collaborative called DCFlex, led by the Electric Power Research Institute, PJM is partnering with Emerald AI and others to demonstrate the capabilities of a more novel source of flexibility – compute flexibility. Compute flexibility is a process to reduce the energy intensity of data center computational jobs with minimal customer service impacts in order to lower the overall demand of the data center. Emerald AI is demonstrating this technology at multiple data centers across the PJM service area, including an NVIDIA AI factory in Manassas, Virginia.



Source: Emerald AI

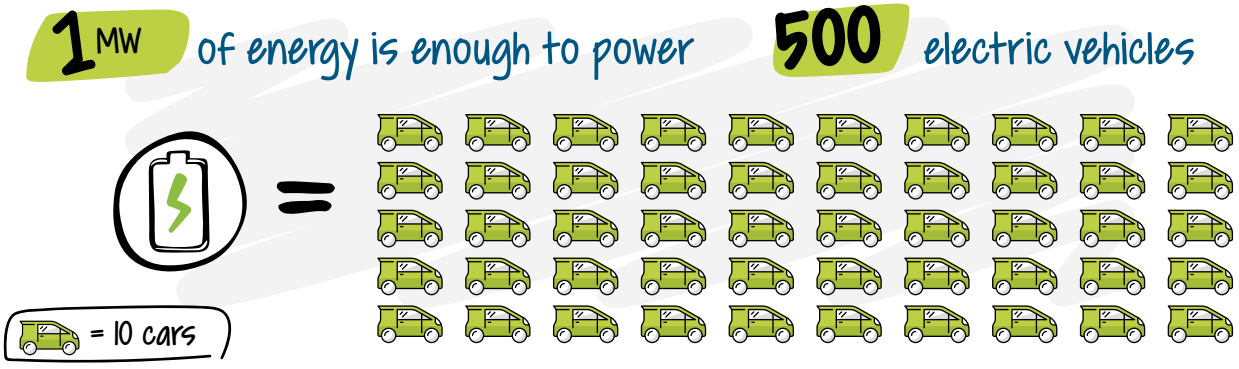
Energy Storage and Hybrid Resources

Efficient and reliable grid operations in an era that features a greater role for renewable resources in energy production will require more electric system flexibility and essential reliability services being provided by new resource types. PJM's interest in energy storage reflects this trend.

Energy storage can help grid operators keep the power supply stable when wind, solar or other variable resources are changing their output due to weather conditions, or more traditional resources are unavailable. It also can improve the efficiency of the transmission system by making better use of existing transmission and distribution networks as well as existing generation sources.

In the past, PJM has worked with various companies and national laboratories to advance the use and application of energy storage and ensure that the PJM wholesale market is capable of allowing all forms of energy storage to participate, be properly valued and compete in the market.

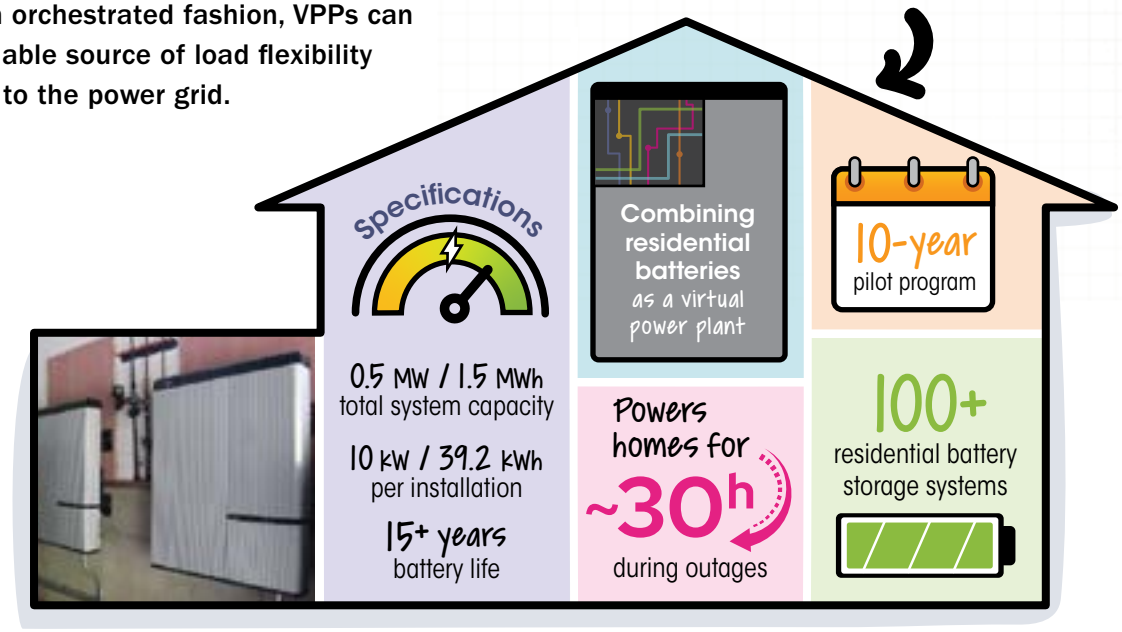
Today, approximately 5,000 MW of pumped storage hydro, 420 MW of grid-connected battery and flywheel energy storage, and approximately 200 MW of behind-the-meter thermal and battery energy storage are qualified to participate in the PJM markets. This includes everything from large central station generation plants connected at transmission to small kilowatt-level behind-the-meter applications. Energy storage is expected to grow in the region significantly, with nearly 7,000 MW of stand-alone storage and solar-storage hybrid resources cleared to start building as of Q1 2026. In December 2019, PJM implemented the Energy Storage Resources Participation Model in order



to allow energy storage resources (ESR) to provide all market services that they are technically capable of offering. Specifically, the ESR market model permits storage resources to offer, be dispatched for, and set price at negative megawatts. Building on the ESR Participation Model, PJM also developed a market participation pathway for hybrid resources — multiple technologies behind one Point of Interconnection operating in the market as one unit. Today, the hybrid resources market model permits the hybridization of all inverter-based technologies (e.g., solar plus storage, wind plus storage, wind plus solar) and also non-inverter-based technologies, such as natural gas plus storage.

Virtual Power Plants

Virtual power plants (VPPs) are generally considered to be a connected aggregation of distributed energy resource (DER) technologies. When responding together in an orchestrated fashion, VPPs can provide a valuable source of load flexibility or generation to the power grid.



In March 2021, FERC issued a comprehensive rulemaking on DER aggregation, called Order 2222, which required that wholesale market operators develop a market participation model for DER aggregation, or VPPs. PJM has worked closely with stakeholders, utilities, aggregators, state policymakers and FERC to design and implement this new market participation model for VPPs that increases market access, enhances market competition and promotes reliability.

To demonstrate the value of VPPs at both the retail and wholesale level, PJM and Delmarva Power partnered to explore how the new Elk Neck Battery Storage VPP could participate in the region's wholesale market for ancillary services.

The project involves a residential community located on the Elk Neck Peninsula in Cecil County, Maryland. Each of the 110 homes involved is equipped with battery storage that can serve the energy needs of the individual homeowners or, aggregated and controlled together, provide reliability services to the local distribution system — as well as the RTO — by both charging and discharging from the grid.

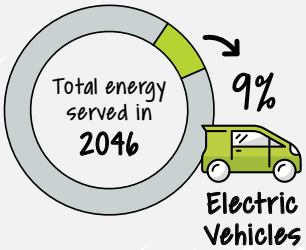
Budderfly, a San Francisco-based provider of DER control, orchestration and aggregation platforms, is collaborating with Delmarva on the project.

The project was approved by the Maryland Public Service Commission under the Maryland Energy Storage Pilot Program.

Electric Vehicles

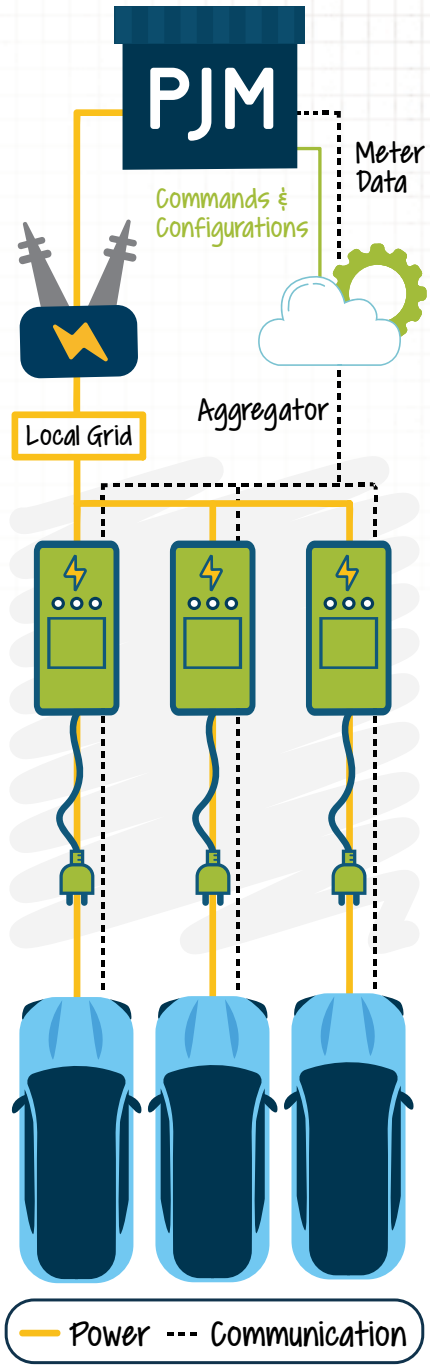
The electrification of transportation continues to be a trend driving demand growth in the electric power sector. Approximately 1 in 10 light-duty vehicles sold in the United States is now electric.

PJM forecasts that electric vehicle (EV) growth in the region will constitute approximately 29,000 MW of peak load and require 129,000 MWh of energy by 2046. EVs will therefore comprise around 7% of peak load and 9% of total energy served in 2046.[1]



While this growth will require additional investment in generation, transmission and distribution to serve, EVs can also be a boon to grid operations and the efficient use of infrastructure by shifting when they charge to hours of lower demand or lower cost energy (i.e., overnight or hours of high renewable energy production). Not only can this reduce stress on the grid, it can potentially allow customers to charge EVs at lower cost.

In addition to "managed charging," advanced EV capabilities, such as "Vehicle to Grid," or V2G, continue to be explored by vehicle manufacturers and utilities. This capacity allows EVs not only to manage when they charge but also export power from their batteries back to the grid when it is most valuable to do so. In this concept, EV customers are able to either power their home during a storm outage or sell services back to the grid, generating a revenue stream for the owner. PJM and Delmarva Power are currently testing the V2G concept in Delaware using Ford Mach-E vehicles outfitted with special charging equipment to allow high-power, bidirectional power flow based on operational control signals from the grid.



[1] S&P Global, Commodity Insights, CI Consulting: Electric Vehicle Charging Power Demand Forecast (PDF)

Topology Control and Optimization

Visit PJM.com for a full list of currently identified switching solutions.

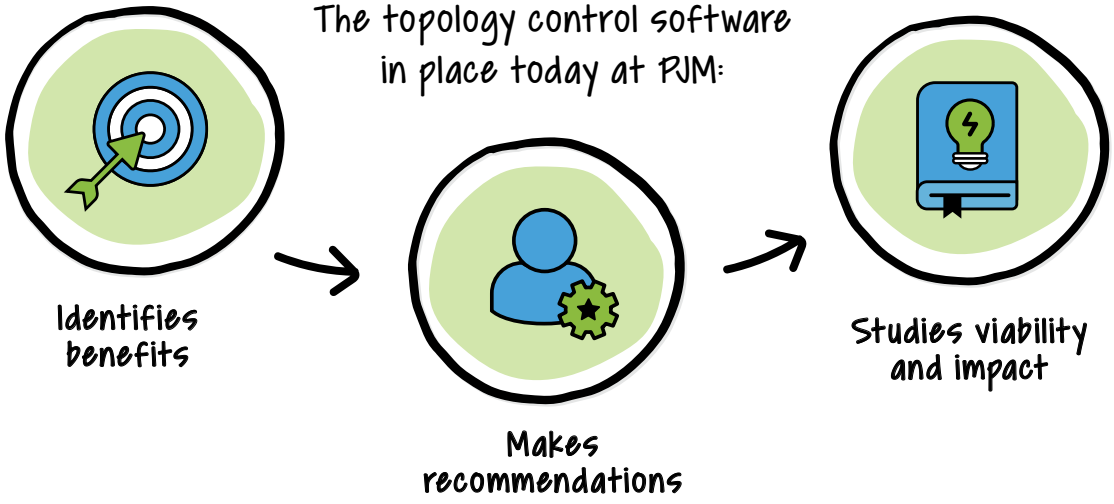
Topology control is the practice of changing the configuration of electrical equipment (e.g., circuit breakers) in order to reroute power flow in the attempt to address reliability and/or congestion concerns. This practice helps increase operational flexibility and lowers generation costs.

Topology control, commonly referred to as switching solutions, is an operational tool used to evaluate the entirety of the PJM footprint and interaction with our neighbors. The identification of the topology changes is traditionally done manually by PJM operators as well as PJM's Transmission Owners (TOs).

The switching procedures may or may not be implemented by PJM based upon system conditions, either projected or actual, and ultimately are implemented solely at the discretion of PJM and its TOs.

Topology optimization,
in an attempt to speed up and broaden the ability to identify potential switching solutions, leverages software to evaluate the current and near-term state of the system.

The topology control software in place today at PJM:



PJM software runs every 15 minutes
Advances on the practice of manually identifying topology changes

Provides ongoing assessment of network configurations and recommended actions
Suggested actions are appropriate and identified where system reliability can be maintained

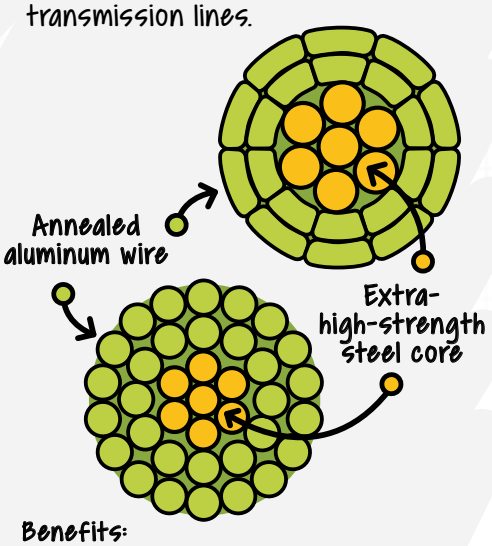
Advanced Conductors

Advanced conductors employ present and future transmission line technologies whose power-flow capacities exceed that of conventional aluminum conductor steel reinforced conductors. These conductors can be used to construct new lines or to reconductor existing lines.

Advanced conductors encapsulate a broad range of transmission line technologies with the goal of increasing power-flow capacities. Each transmission line technology has its own potential benefits and identified barriers and is considered by PJM Transmission Owners (TOs) on a case-by-case basis.

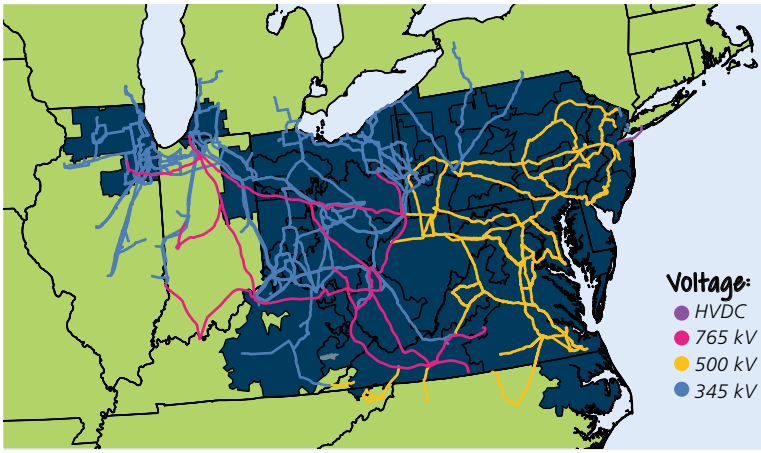
Conductors act as a critical pieces of the transmission network and are used to transmit power from point to point. Through advancements in transmission line technologies, the use of advanced conductors may aid in the increase of transmission capacity growth. These conductor technologies, however, may require special handling, installation and/or maintenance as compared with traditional conductor materials.

Several PJM TOs have installed advanced conductors, such as high-temp/low-sag **aluminum conductor steel supported** (ACSS) transmission lines.



Benefits:

- *Reduced tower cost*
- *Decreased sag*
- *Increased operating temperature*



Transmission lines make up the backbone of the PJM footprint and help serve multiple states and millions of people.

Given the miles of transmission lines in the PJM footprint, the ability to increase power-flow capacities is a desirable effect. PJM TOs evaluate the use of transmission line technologies and their potential impact on the grid.

Key Statistics	PJM Today
Millions of people served	67+
Miles of transmission lines (Bulk Electric System)	88,417
Megawatts of generating capacity	185,989
Square miles of territory	368,906
Area served	13 states + D.C.

National laboratories continue to research and report on specific transmission line technologies, highlighting their individual characteristics and use cases. See the December 2023 Idaho National Laboratory Advanced Conductor Scan Report (PDF).

PJM Advanced Technology Pilot Program

Visit PJM's website to learn more.

Since PJM is an independent and profit-neutral company, it does not directly fund pilot projects. Rather, it is an active participant in the project, providing human resources, analysis and other expertise. In certain cases, PJM offers its corporate campus or other physical resources as a test site for new technology.

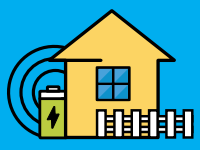
PJM's pilot program provides a transparent testing ground to study the viability of integrating emerging technologies that enhance system reliability, operational and market efficiency, and resilience.

PJM is involved in a number of proposed or active advanced technology pilot projects across its footprint. These projects cover a broad spectrum of technologies and concepts, including energy storage, dynamic flexible load response, transmission operations, distributed energy resources and microgrids.

These projects vary by topic, scope, funding source and duration, but they have a common theme of contributing to the reliable and cost-efficient operation of the electric grid of the future.

Continue learning about PJM's Advanced Technology Pilot Program.

2021



FERC's Order 2222 sets requirements for DER aggregation.

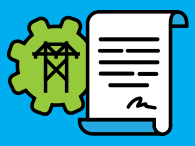
Learn more

2022

Installed synchrophasor count reaches 750 in the PJM footprint.

Learn more

2024



FERC Order 1920 on regional transmission planning emphasizes the use of grid-enhancing technologies.

Learn more

2025

At the end of 2025, PJM was studying more than 8,000 MW of storage and hybrid projects for requested interconnection.

Learn more

2026

EPRI DCFlex, NVIDIA, Emerald AI and PJM demonstrate "compute flexibility."

Learn more