Advanced Conductors

Grid Enhancing Technologies: Technical Reference Guide

2024

For Public Use

Purpose

PJM supports the transparent, cost-effective, efficient and reliable deployment of Grid Enhancing Technologies (GETs) and Alternative Transmission Technologies (ATTs) on the PJM system consistent with requirements of PJM's governing documents and manuals. PJM seeks to raise awareness of GETs applications and benefits without overstating their ability to supplant necessary transmission investment. However, the details within this guide may not be perfectly applicable to every project proposal, subset of the technology, transmission zone, or local and state regulations. Rather, the guide seeks to provide a broader understanding for the technology's background, technical and modeling considerations, potential benefits and barriers, as well as regulatory context.

This technical reference guide is intended to aid the evaluation of advanced conductors in the region PJM serves. Advanced conductors include present and future transmission line technologies whose power flow capacities exceed the power flow capacities of conventional aluminum conductor steel reinforced conductors.[1] PJM cannot prescribe the use of advanced conductors, but provides criteria to consider when evaluating such projects.

Background

Conductors are a critical part of the transmission network and allow for the flow of energy across approximately 88,000 miles of transmission lines that make up the PJM system. Material sciences and associated manufacturing practices have made advancements that can be utilized in overhead transmission lines to enhance transmission capacity and/or attain infrastructure footprint reductions and objectives.

Conductor enhancements include, but are not limited to:

- Superconducting cables
- Advanced composite conductors
- High temperature low-sag conductors
- Fiber optic temperature sensing conductors
- Advanced overhead conductors[1]

In addition to meeting unique siting requirements and the potential ability to carry additional capacity, the number of outages and maintenance cost may decrease based on proposed increases in robustness associated with advanced conductors. Whether it is new construction, or used in the reconductoring process, advanced conductors may be considered among other conductor materials in terms of cost, reliability and performance. Transmission providers can review vendor specifications as well as independent research from organizations and national labs to better compare advanced or traditional conductor options.

[1] FERC Order No. 2023-A ¶ 631

Technical Considerations

All proposed uses of advanced conductors should consider substation equipment, reliability and/or market impacts to other facilities including those outside the PJM region and any additional transmission work needed to realize the potential benefits. PJM recommends that proposed used of advanced conductors, like traditional conductors, be circumscribed to those which:

1 | Are restricted by conductor temperature and power transmitting ability, but are not limited by system reliability criteria including voltage drop, stability, nor substation Transmission Facility Ratings

2 | Economic projects, submitted for congestion relief as part of competitive Market Efficiency windows, that meet PJM's market efficiency benefit/cost ratio threshold of at least 1.25:1, if applicable[2]

3 | Consider the age and conditions of supporting infrastructure (e.g., transmission poles/towers) as part of the overall project cost and scope

4 | Provide governmentally prescribed or reliability gain in terms of reduced footprint, including:

(a) Visible structure improvement
(b) Tower height objectives
(c) Minimization of land use
(d) Operation and maintenance impact over the lifetime of the investment
(e) Consideration and coordination for urban and infrastructure planning
(f) Improved resilience in extreme weather conditions

Transmission providers should be cognizant of the initial costs associated with advanced conductors against future benefit over a time horizon compliant with FERC orders described in sections below.

Projects that meet one or many of the above technical considerations do not necessitate the use of advanced conductors, but rather suggest a consideration of possible use and further evaluation.

Advanced Conductor – Evaluation Matrix

	In Use in PJM Today	Potential Opportunity	Not Currently Applicable
Congestion Management	▲		
Thermal Support	▲		
Voltage Support*			▲
Stability Support*			▲
Generation Interconnection		▲	
Economic Planning		▲	
Long-Term Reliability Planning		▲	

[2] PJM Manual 14B, Attachment E: Market Efficiency Analysis Economic Benefit/Cost Ratio Threshold Test

**Voltage Support and Stability Support may also be inherently addressed but may not be the primary driver for use.*

Modeling Considerations

PJM anticipates that advanced conductors would be modeled similarly to existing conductors, and additional benefits would be reflected in the ratings associated with the equipment when the conductor is the limiting element of the facility. If a given project's complexity in modeling or operation requires PJM, a member Transmission Owner (TO), or impacted PJM neighbor to invest in technological improvements to assure system reliability and market continuity, such investments would need to be factored into the project evaluation.

With respect to the primary PJM utilization of advanced conductors in terms of Facility Ratings, PJM is prepared to model and evaluate corresponding impacts across PJM systems in PJM's operations, markets and planning functions. Ancillary abilities and services would need to be compliant with PJM Manuals based on the proposed usage. Modeling specifications associated with those services would be considered independently from as well as in concert with the primary usage of advanced conductors.

TOs should operate equipment in accordance with PJM Manuals and follow PJM instructions related to owner's responsibilities.

Potential Benefits

Since many different line technologies can be referred to as advanced conductors, this section will cover, at a high level, the potential benefits of multiple different conductors as long as the power flow capacities exceed the power flow capacities of conventional aluminum conductor steel reinforced conductors. The benefits are not all encompassing in terms of their application to each individual conductor material. Additional review of the specific conductor and the scenario in which it is being considered must be taken into account when evaluating the potential benefits and limitations.

For example, the use of some advanced conductors may allow for extended periods of operation at higher conductor temperatures. This can have a direct impact on emergency Facility Rating capabilities on the associated lines. The reduced impact, as compared to traditional conductor materials, from thermal heating could result in lower line losses and reduced sag.

Reducing sag can allow for longer transmission line spans and highlights the potential use of advanced conductors for water crossings. Lines with advanced conductors may also utilize structures with lower tower height because of the clearance gains associated with a reduced sag design. Regardless of potential application, the use of advanced conductors must still satisfy the mechanical and sag requirements under all extreme weather conditions based on National Electrical Safety Code (NESC) requirements and utility practices.

Potential height reductions in transmission structures, or materials associated with such structures, and clearances may impact the overall cost of projects. Costs comparisons associated with advanced conductor projects against other project proposals was discussed at length within FERC Order 1920.[3] Dependent on that time horizon, projects that utilize advanced conductors may result in lower total costs.

[3] FERC Order No. 1920: Building for the Future Through Electric Regional Transmission Planning and Cost Allocation, 187 FERC ¶ 61,068, at P 187,

Although some of these benefits would only be realized with certain projects, one of the largest proposed benefits is via the use of advanced conductors as part of reconductoring an existing line. While benefits would be on a case-by-case basis, utilizing rights-of-way, although not unique to advanced conductors, may increase power flow capacities on a given path. Reconductoring with advanced conductors, as previously stated, must consider the existing structures and their ability to support the proposed conductor material. The current age of infrastructure may allow for consideration of reconductoring and the opportunity to consider the use of advanced conductors.

Seventy percent of transmission lines are over 25 years old and approaching the end of their typical 50–80-year lifecycle.[4]

Beyond the impact of the conductor material itself, some advanced conductor lines also have the ability to embed fiber-optic sensors along the line.[5] The sensors would allow for real-time readings for data such as temperature, sag and loading capabilities. This functionality appears to align with proposed benefits from DLR, but would be subject to the technical considerations and requirements for Transmission Facility Ratings.

Identified Barriers

Despite potential cost savings over extended periods of time, there are higher initial costs associated with advanced conductors. Advanced conductors may also require additional costs in terms of training, handling and/or materials used for proper installation and maintenance. The beneficiaries and time horizon to consider when comparing associated costs of proposals can be complex and add levels of uncertainty when it comes to investing in these technologies.

Additional complexities are not solely limited to the cost of the project; there may also be increased complexity in terms of installation, operation, rating calculations and maintenance. Continued evaluation on the lifespan and longevity (e.g., a conductor's susceptibility to brittle damage[6] and resilience to weather conditions) of certain conductor materials would provide critical insight needed to evaluate the proposed use of an advanced conductor. Furthermore, traditional conductor materials have an extensive performance history and operational understanding that some advanced conductors may not.

Industry standards on design should be developed in order to ensure consistent evaluation and applicability across transmission providers and equipment manufacturers.

Technical considerations must also be taken into account to help achieve the technology's full benefits. Proposed installations must consider terminal equipment constraints and may require additional upgrades to realize the proposed benefits. Project proposals that are limited by substation equipment would need to consider whether it is efficient and cost-effective to upgrade substation equipment in order to realize the proposed benefits of advanced conductors. Continued industry assessment, lessons learned and specific conductor evaluation[7] are critical to understanding the potential use of advanced conductors while recognizing the specific barriers and associated costs with their installation and long-term use.

[4] "What does it take to modernize the U.S. electric grid?" United States Department of Energy, Oct. 19, 2023

[5] Advanced Conductor Scan Report, Idaho National Laboratory, Dec. 2023

[6] "Analysis of ACCC failure of composite core glass transition temperature reduction due to brittle damage," Engineering Failure Analysis, Dec. 2022

[7] Advanced Conductor Scan Report, Idaho National Laboratory, Dec. 2023

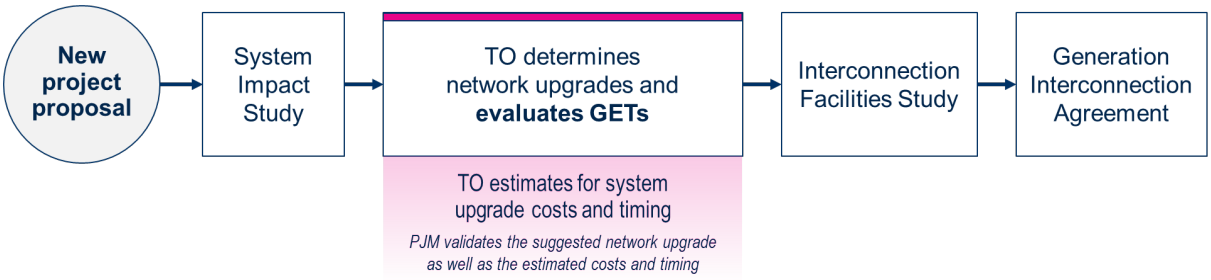
FERC Order 2023

On July 28, 2023, the Federal Energy Regulatory Commission (FERC) issued Order 2023,[8] a Final Rule adopting reforms to address interconnection queue backlogs and promote new technologies through its forms of generator interconnection procedures and agreements. In addition to ordering reforms to implement a first-ready, first-served cluster study process, the Commission addresses reforms to incorporate technological advancements into the interconnection process. The Final Rule requires transmission providers to evaluate, with transmission provider discretion around deployment, the following alternative transmission technologies in their cluster studies, including any studies and re-studies: static synchronous compensators, static VAR compensators, advanced power flow control devices, transmission switching, synchronous condensers, voltage source converters, advanced conductors and tower lifting.[9]

The Final Rule emphasizes that the transmission provider will retain the sole discretion to determine whether an alternative transmission technology should be used, consistent with good utility practice, applicable reliability standards and other applicable regulatory requirements.

The Final Rule also requires that transmission providers include in their feasibility study reports and system impact study reports an explanation of the results of the evaluation for each of the aforementioned alternative transmission technologies for feasibility, cost and time savings as an alternative to a traditional network upgrade. **Figure 1** details when GETs are evaluated within a simplified generation interconnection process.

Figure 1. Simplified Generation Interconnection[10] Flowchart Considering GETs



PJM sought an independent entity variation with respect to the Final Rule's requirement that transmission providers include in interconnection study reports the results of their evaluation of the feasibility, cost and time savings of GETs as an alternative to traditional transmission technologies. In accordance with PJM's FERC Order 2023 and 2023A compliance filing,[11] the PJM Tariff already accounts for alternative transmission technologies in the interconnection process, as all of the enumerated GETs already are considered and studied, as necessary in the course of interconnection studies in the PJM footprint.

[8] FERC Order No. 2023

[9] FERC Order No. 2023, ¶1578

[10] Generation Interconnection Fact Sheet, PJM Interconnection

[11] Order Nos. 2023 and 2023-A Compliance Filing of PJM Interconnection

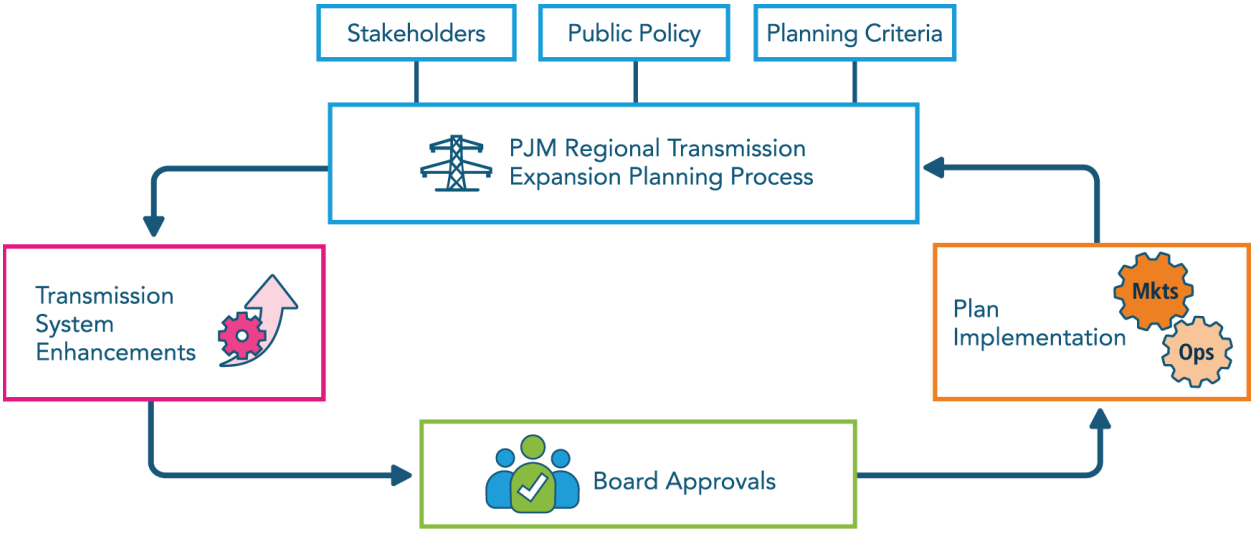
FERC Order 1920

FERC Order 1920[12] requires transmission providers to consider dynamic line ratings, advanced power flow control devices, advanced conductors and transmission switching for each identified transmission need in long-term regional transmission planning (LTRTP) and existing FERC Order 1000 regional transmission planning processes. The Order requires transmission providers to consider each of the enumerated technologies when evaluating new regional transmission facilities, as well as upgrades to existing transmission facilities and explain in sufficient detail why any of the enumerated technologies are not selected. The selection and use of any of the technologies that are incorporated into an existing transmission facility should be treated as an upgrade to an existing transmission facility. Therefore, an incumbent transmission owner would be designated. For a new selected regional transmission facility, the transmission developer (incumbent or nonincumbent) is designated.

PJM is prepared to account for the operation and study of advanced conductors in compliance with FERC Order 1920 as issued on May 13, 2024. A key consideration is that benefits for all projects be calculated on the same time horizon to properly compare projects.[13] As such, PJM will require a time horizon that covers, at a minimum, 20 years starting from the estimated in-service date when comparing proposals within the LTRTP process. Projects including alternative transmission technologies proposed in an Order 1000 window will be evaluated over existing time horizons. As with all GETs, PJM recommends that proposals evaluate the technical considerations laid out in this technical reference guide as it applies to the identified issue.

Within the Regional Transmission Expansion Plan (RTEP), it is incumbent on the proposing entity to evaluate and suggest the use of advanced conductors, or any other GETs. As described in **Figure 2**, PJM receives input from states and other stakeholders, and in conjunction with the planning criteria, identifies the baseline projects. Proposing entities are then able to submit, for PJM consideration as part of the RTEP process, transmission system enhancements that may include, among other things, advanced conductors and GETs.

Figure 2. RTEP Process – RTO Perspective



[12] FERC Order No. 1920, ¶1198

[13] FERC Order No. 1920, ¶848