Dynamic Line Ratings

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 guide discusses the implementation of Dynamic Line Ratings (DLRs) in the PJM region. DLR is defined as "a transmission line rating that applies to a time period of not greater than one hour and reflects up-to-date forecasts of inputs such as (but not limited to) ambient air temperature, wind, solar heating, transmission line tension, or transmission line sag."[1] PJM cannot prescribe the use of DLRs but provides criteria to consider when evaluating proposed implementations.

Background

For over two decades, PJM has had an operations ratings framework that allows for the inclusion of ambient conditions into such ratings. FERC Order 881 (discussed later) expands that framework to cover hourly ratings that incorporate forecasted ambient conditions for the next 10 days. In support of PJM's operations, PJM's planning reliability studies leverage seasonal ratings (summer/winter) due to the nature of their work and the uncertainty of ambient condition forecasts within PJM's long-term planning time horizon.

PJM facility owners have had the ability to leverage PJM's full ambient condition framework to reflect their Facility Ratings within the PJM operations time horizon and incorporate, based on their rating methodology, any impacts on sustained transfer capability within their seasonal ratings to be used by PJM Planning. By accounting for ambient temperatures, Ambient Adjusted Ratings (AARs) factor in the impact that regional temperature has on the transfer capability and can be updated as those conditions change throughout a day. Both seasonal rating and AAR methodologies may be viewed as conservative due to their regional proxy approach, as compared to DLRs, which are calculated based on actual and forecasted ambient conditions specific to the associated conductors and incorporates limits from non-conductor elements.

Generally speaking, DLR deployments involve the installation of a data collection sensor on or near an existing transmission line to collect real-time conductor information. DLR technology does not modify the physical characteristics of a transmission line, but rather provides a means for determining, closer to use, ratings by using specialized sensors that provide an indication of the line's limitations.

Sensor technologies may include:

- Weather stations
- Electromagnetic fields
- Light Detection And Ranging (LiDAR)
- Vibration
- Tension
- Thermal cameras

[1] NOPR, 179 FERC ¶ 61,028 at page 259 n.408 (citations omitted); see also FERC Order No. 881, 177 FERC ¶ 61,179 at P 7; Implementation of Dynamic Line Ratings, 178 FERC ¶ 61,110 at P 1

By accounting for real-time conductor and forecasted weather conditions, DLR systems are able to incorporate this data extemporaneously into the Facility Rating calculations using discrete data that would otherwise be approximated when used in predetermined calculations/methods.

Technical Considerations

Overall, there are limited technical considerations in relation to the installation of DLRs beyond the requirements for all equipment rating systems and operational requirements (per PJM Manuals[2]) in PJM. Transmission providers should be cognizant of:

- The initial costs associated with DLRs
- Necessary software changes
- Impact to their Facility Rating methodology
- Ongoing operations and maintenance costs
- Differences in equipment and/or software utilized across various vendors
- Training and support and efforts to incorporate such a Facility Rating calculation methodology against future benefits over a time horizon compliant with FERC orders described in sections below, or in alignment with their company strategy

This is particularly true for an initial foray into the technology. From a PJM usage perspective, DLR installations provide the greatest benefit when they are functioning within or are part of:

1 | A network that is conductor limited and considers associated terminal/station equipment

2 | Locations that have experienced historic congestion that would have been reduced if conductor ratings were higher[3]

3 | Locations forecasted to experience congestion that would be reduced with increased conductor ratings

4 | Locations that do not create, nor exacerbate, congestion or reliability issues to nearby locations

5 | Locations with adequate cooling effects from wind patterns relative to the conductor[4]

[2] PJM Manual 1: Control Center and Data Exchange Requirements, PJM Manual 3: Transmission Operations, PJM Manual 3A: Energy Management System (EMS) Model Updates and Quality Assurance (QA)

[3] PJM Comments, Docket No. AD22-5 at page 9 (filed May 9, 2022) recommends requiring DLRs on any transmission line with annual congestion costs of at least $2 million.

[4] FERC ANOPR RM24-6-000 ¶ 118 proposes a wind requirement on transmission lines where at least 75% of the length of the transmission line is located in areas with historical average wind speeds of at least 3 meters per second (m/s) (6.7 miles per hour) measured at 10 meters above the ground, roughly the height of most transmission lines, based on National Renewable Laboratory (NREL) data sources.

6 | Projects that are able to adhere to PJM's transmission operations guidelines as detailed in PJM Manual 3, Section 2.1.1.2 including, but not limited to:

(a) Real-time and forecasted rating requirements around submission

(b) Backup procedures

(c) Facility awareness/notification timeline and process

(d) TO and PJM actions/considerations around DLR outages

7 | Projects that consider current rating methodology and the underlying assumptions utilized when calculating anticipated impact

8 | 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[5]

Based on the proposed benefits, the installation of DLRs may result in overall regional, or system wide, reduction in congestion costs when compared to other Facility Rating methodologies if done purposefully and ambient conditions are coincident with congestion. Likewise, the expanded accuracy that DLRs' dynamic Facility Rating calculations produce may lead to gained reliability when compared to traditional methods, even if it situationally increases congestion. By accurately reflecting additional transmission capacity based on those conditions, there may be a reduction in overall system costs by allowing for an increased output of least-cost generation while leveraging an advanced technology with a predictable reliability benefit.

Dynamic Line Ratings – 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			▲

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

Modeling Considerations

TOs should operate equipment in accordance with the PJM Manuals and follow PJM instructions related to PJM responsibilities. Please refer to PJM Manual 1: Control Center and Data Exchange Requirement, PJM Manual 3: Transmission Operations, and PJM Manual 3A: Energy Management System (EMS) Model Updates and Quality Assurance (QA) for additional details pertaining to modeling specifications and operational requirements.

Potential Benefits

DLR devices report the change in line ampacity with consideration of ambient temperature, solar irradiance and effects of wind cooling. As these conditions can change minute by minute, DLR systems are able to update line ratings in or near real time to accurately reflect transfer capabilities. Accounting for these features, transfer capabilities may increase based on the updated ratings and result in a decrease in associated congestion costs. Lower cost generation restricted by non-DLR methodologies may also increase output and decrease system costs.

> *While DLR is not a substitute for system reliability upgrades, new and innovative technologies such as DLR may provide congestion relief in the near term at lower expense.*[6]

It should be noted that implementing DLR systems does not guarantee transfer capability will increase nor reduce congestion. Based on the environmental conditions, as noted above, transfer capabilities may decrease and result in an increase in associated congestion costs. DLR systems accurately reflect the transfer capability based on their measured and forecasted environmental and physical factors whether that results in an increase, decrease, or insignificant change as compared to other Facility Rating methodologies.

Identified Barriers

Despite the potential benefits described in the section above, integration of DLRs in the PJM system is limited to date. This may be a result of several identified barriers that should be factored into DLR system consideration or installation. In particular, the greatest barrier to DLR adoption is the initial investment, training and systems incorporation. For a given owner, further applications of the technology spread the costs and potential benefits beyond that of a singular installation.

DLR systems also have increased level of complexity as compared to traditional methods in terms of the development of the underlying algorithm that is used to incorporate the additional sensor measurements to calculate line ratings as well as expanded maintenance and technology infrastructures.

Additional time may be required to validate the accuracy and reliability of the calculated ratings, especially true for the initial system installations, and require a systematic fall back if the DLR calculation proves to be inaccurate or fails. PJM is committed to working with the Facility Owner throughout this validation process as they incorporate DLRs into their Facility Rating methodology.

[6] Dynamic Line Rate Report, United States Department of Energy, June 2019

The use of DLRs may impact congestion costs to the system, but must be made in balance with the cost, time and training associated with integrating DLR systems across company software and Energy Management Systems (EMS). TOs and rate-regulated companies must also consider the return on equity of the associated costs.

Although it may be relatively minimal in terms of individual installations, the computational requirements to consume and utilize the additional sensor data may introduce or exacerbate concerns with storage and use of increasing data volumes. This impact should be considered in regard to the increasing number of installations within a region and the software and network robustness needed to handle them. Wide-scale deployment may lead to additional cost without a corresponding reduction to congestion or a realized transmission capacity benefit.

FERC Order 881

Issued on Dec. 16, 2021, FERC Order 881[7] proposed the definition of an AAR. PJM's FERC-approved filing[8] around that Order refined the AAR definition as a Transmission Facility Rating that:

1 | Applies to a time period of not greater than one hour

2 | Reflects an up-to-date forecast of ambient air temperature across the time period to which the rating applies

3 | Reflects the absence of solar heating during nighttime periods where the local sunrise/sunset times used to determine daytime and nighttime periods are updated at least monthly, if not more frequently

4 | Is calculated at least each hour, if not more frequently.

The Order requires that transmission providers use hourly AARs for the time horizon within 10 days of the operating day. Beyond 10 days, in the operations and operations planning time horizons, and in determination of available transfer capability, transmission providers will utilize Seasonal Facility Ratings, which will be monthly. FERC Order 881's hourly and seasonal approaches do not apply to transmission planning.[9]

PJM views DLR installations as a real-time or near-term Facility Rating Methodology, but acknowledges they may provide benefit that impacts long-term congestion planning as discussed in sections below.

[7] FERC Order No. 881

[8] PJM Order Nos. 881, 881-A Compliance Filing

[9] FERC Order No. 881 ¶ 203

FERC Order 2023

On July 28, 2023, FERC issued Order 2023,[10] 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, though **not** deploy, alternative transmission technologies in their cluster studies such as static synchronous compensators, static VAR compensators, advanced power flow control devices, transmission switching, synchronous condensers, voltage source converters, advanced conductors, and tower lifting including any in any studies and re-studies.

PJM agrees with the decision to omit DLR from the Order as part of generation interconnection planning. The benefits associated with DLR are dependent on favorable weather and congestion patterns and do not provide adequate substitutions as compared to traditional network upgrades within the generation interconnection process. For these reasons, PJM does not incorporate the recommendation of DLR installations as part of the generation interconnection planning process and in association with required network upgrades.

FERC Order 1920

FERC Order No. 1920[11] 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 No. 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 newly selected regional transmission facility, the transmission developer (incumbent or nonincumbent) is designated.

PJM will consider DLR in reliability studies through the projected impact to ratings that are provided by the TOs for the cases. This would allow for evaluation of worst-case scenario studies for projects that include DLR, or a combination of DLR and other upgrades to address identified planning violations, while recognizing sustained impacts to transfer capability as reflected in the ratings. This does not mean that additional ratings, nor different temperature sets, would be required specifically for lines with DLR. Rating information submitted for these studies would remain consistent with existing practices and would reflect the transfer capabilities of the line including any impacts, if any, from DLR and rating methodologies may vary among TOs.

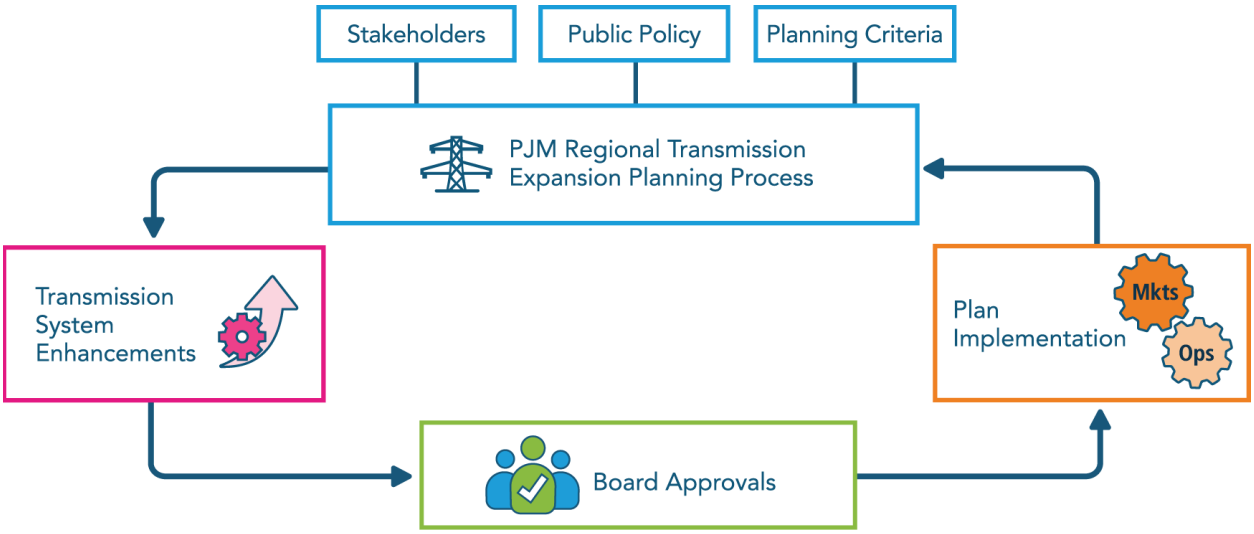
[10] FERC Order No. 2023

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

In addition to that, PJM will also account for DLR within economic planning analysis and the seven enumerated benefits required for project evaluation listed in FERC Order No. 1920. This will allow for the assessment of DLR to reduce future market congestion and long-term economic impact based on the forecasted ratings submitted to PJM. Within the economic planning process, ratings for lines equipped with DLR devices will be modeled incorporating rating changes as implemented in FERC Order 881, including seasonal ratings among others. DLR may impact future needs and reduce congestion, but that benefit is not a substitute for traditional network upgrades needed for system reliability.

Within the Regional Transmission Expansion Plan (RTEP), it is incumbent on the proposing entity to evaluate and suggest the use of DLR, or any other GETs. As described in **Figure 1**, 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, DLR and other GETs.

Figure 1. RTEP Process – RTO Perspective



Related Materials

Dynamic Line Ratings Overview (PDF)

EMS and eDART Implementation (PDF)

Operations Contingency/Outage Impacts (PDF)

Regional Transmission Expansion Plan (RTEP) Impacts (PDF)

Dynamic Line Rating Market Impacts (PDF)

Modeling Dynamic Line Ratings Market Efficiency Planning Process (PDF)

FERC Notice of Proposed Rulemaking and PJM Comments on Transmission Line Ratings (PDF)