Introduction to Dynamic Line Ratings (DLR)

Shaun Murphy
Nicolae Dumitriu
Emerging Technologies Forum (ETF)
August 27,2020

Agenda

- What are Dynamic Line Ratings (DLR)?
- What are the Use Cases for DLR?
- History of Dynamic Line Rating projects at PJM
  - Telemetered ICCP Ratings
  - DLR Pilot Projects
- PROMOD Economic Study
- Additional Considerations of DLR
- Future DLR Discussions in ETF

What are Dynamic Line Ratings?

Static vs Dynamic Line Ratings

STATIC RATINGS

Transmission lines are typically operated using a Static Rating calculated using near worst-case values for assumed weather conditions.

DYNAMIC LINE RATINGS (DLR)

The rating can be calculated in real-time if the variables in the conductor heat balance equation are known.

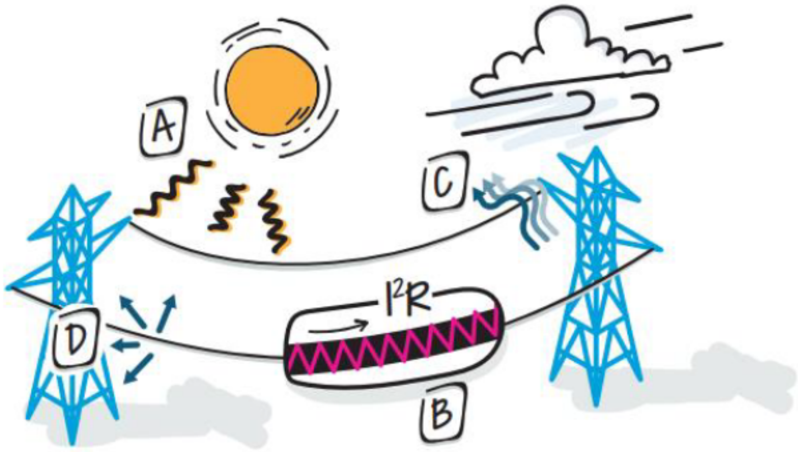
Wind Speed Increase
3 ft/s, 90° angle

→

Capacity Increase
+ 44%

Wind cools the conductor allowing more power to safely be transmitted on the line

Temperature of Overhead Conductors[1]



Conductor temperature is determined by:

A. Sunlight warming the conductor surface
B. Resistive heating (I^2R)
C. Convective cooling by wind
D. Blackbody (radiative) cooling of the conductor
E. Heat capacity of the conductor

1. IEEE Standard 738-2012

Dynamic Line Rating Technologies

Dynamically rated transmission line involve the installation of a data collection sensor on or near an **existing** transmission line asset to collect real-time conductor temperature information.

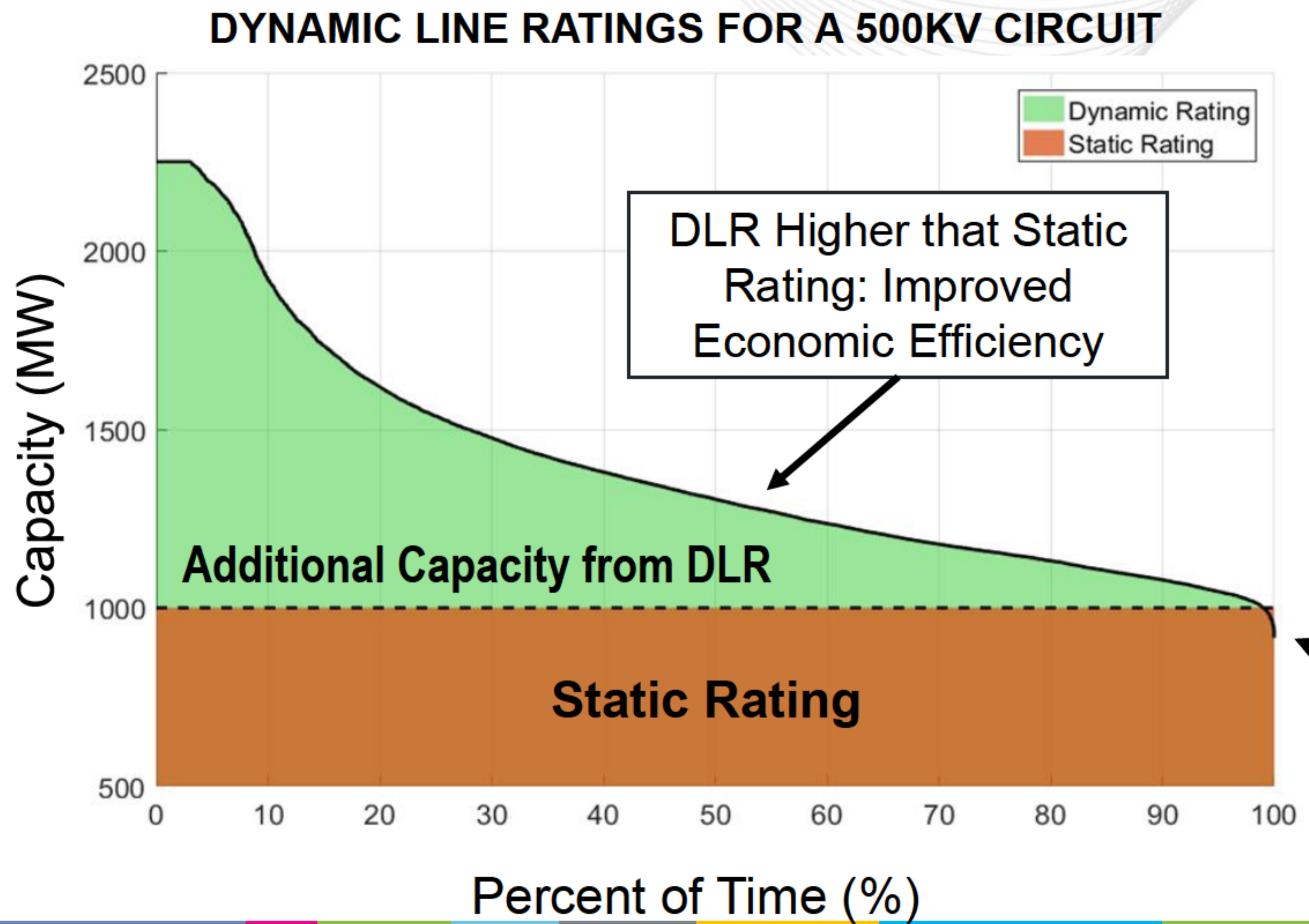
Sensor technologies include:

- Weather Stations
- Electromagnetic Field
- Light Detection And Ranging (LiDAR)
- Vibration
- Tension
- Thermal Cameras

DLR project installations should target:

- Congested transmission facilities where:
- The transmission conductor is the most limiting element

Availability of Additional Capacity from DLR



DLR measures the actual atmospheric conditions which nearly always reveals additional capacity.

Static Ratings are calculated using very conservative assumptions for atmospheric conditions.

DLR Lower than Static Rating: Improved System Reliability

History of DLR Projects at PJM

- Early 2000s: EMS enhancements made to receive telemetered ratings for a small group of transmission lines in PJM. This project lasted ~2 years, and this EMS functionality was last tested in 2015.
- 2016/ 2017: PJM, AEP, and Genscape (LineVision) conducted a DLR pilot on a 345kV transmission line AEP. The focus of this pilot was to gain understanding of:
  - Design & Installation process
  - Passive data collection
  - Estimated economic impacts in an RTO
- 2017/2018: PJM, AEP, and Lindsey conducted a DLR pilot on a 138 kV transmission line in AEP located near a large wind unit with focus on:
  - DLR/ wind unit co-convection

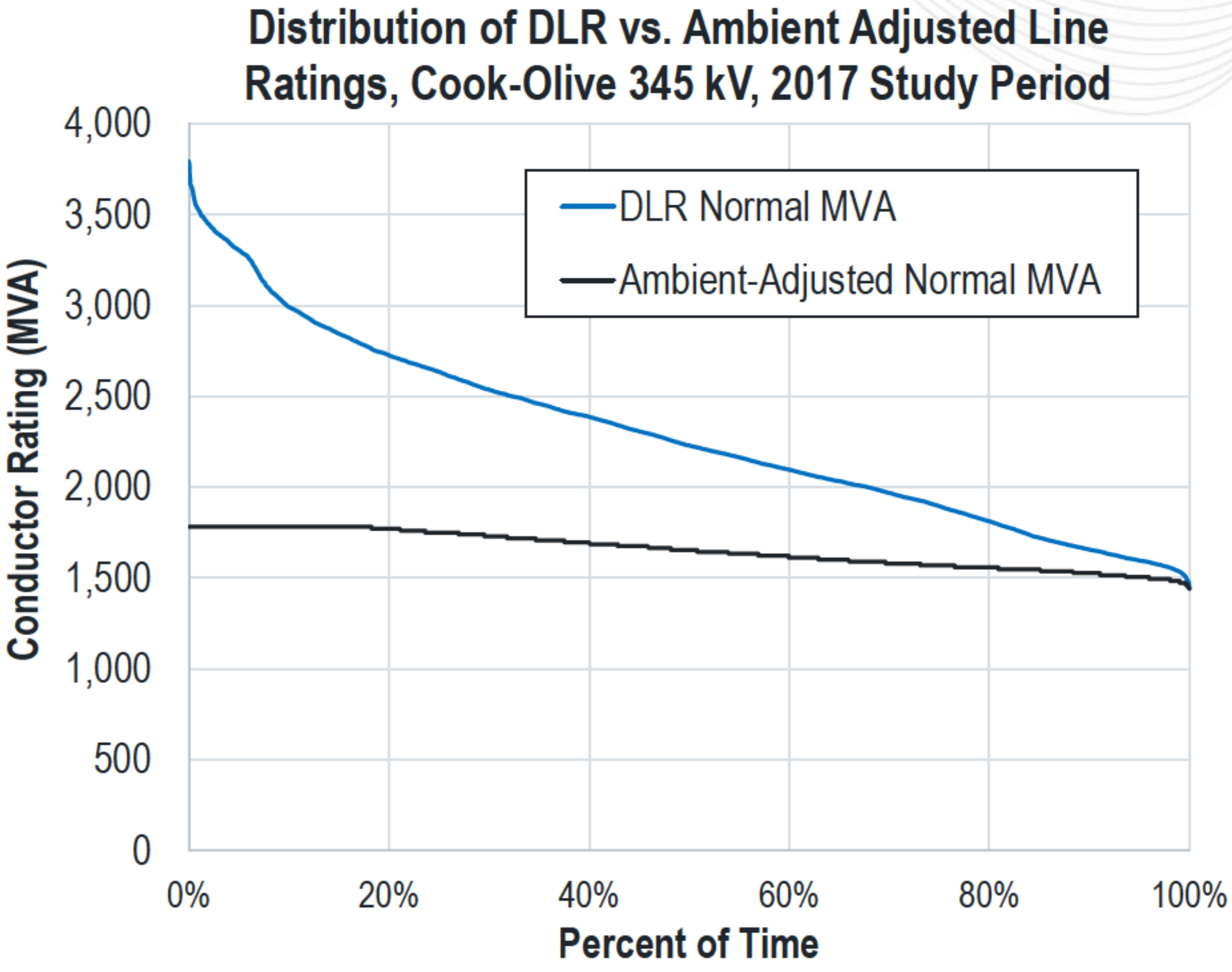
AEP, PJM, and LineVision conducted a research project to quantify the potential economic impacts of DLR

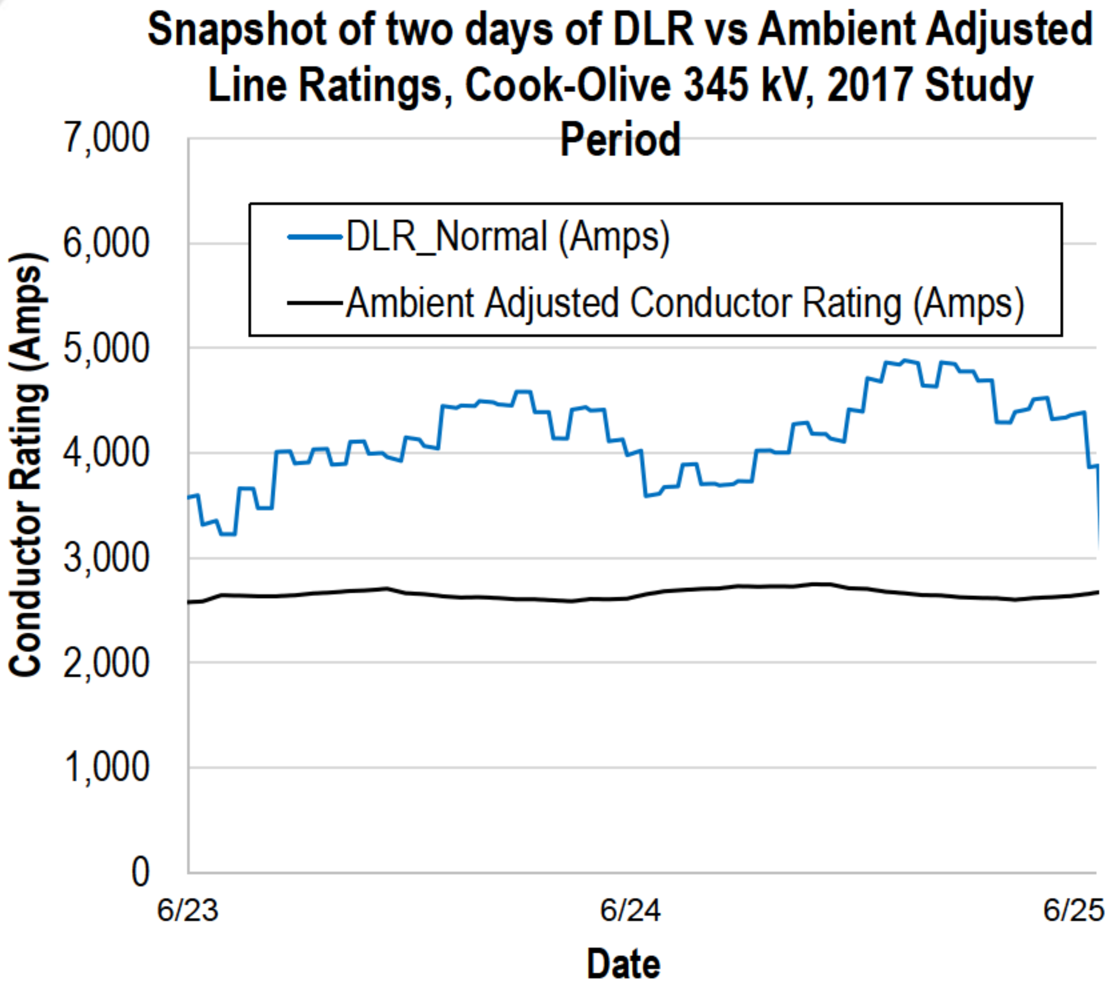
AMERICAN ELECTRIC POWER	*Engineering & Field Support*
LINEVISION	*LineVision DLR System & Installation*
pjm	*Analysis of DLR's Economic Impact*

Project Overview:

- AEP's Cook-Olive 345 kV transmission line selected
- LineVision sensors installed under three (3) spans along the circuit
- Line monitoring data was collected between November 2016 – August 2017
- PJM conducted an economic analysis to determine the potential improvements in system and market efficiency by using DLR in operations
- Project funding was provided by Oak Ridge National Laboratory

DLRs are very favorable relative to Ambient Adjusted Ratings





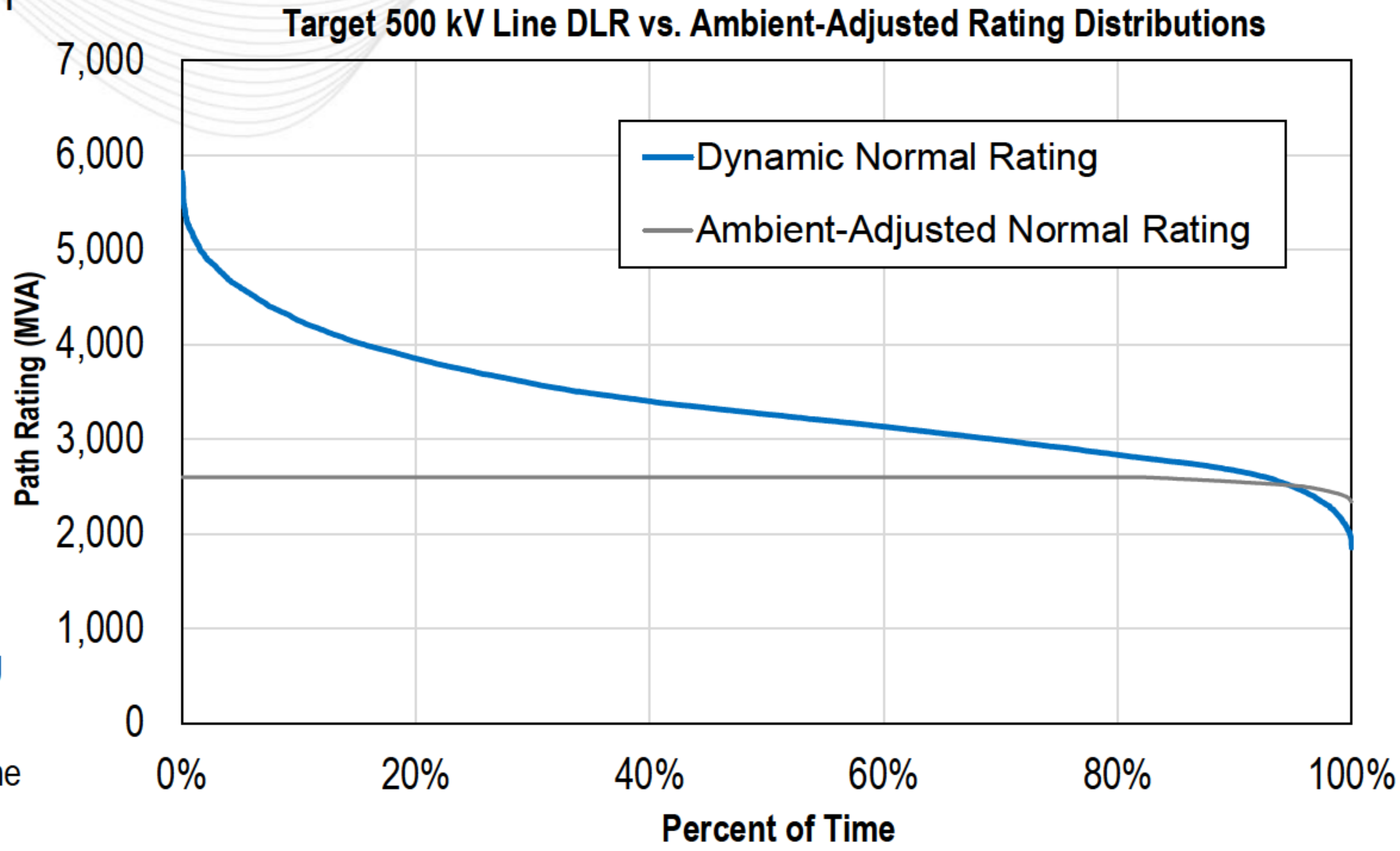
AA Rating Methodology Source: https://edart.pjm.com/reports/PJM_Line_ratings.txt

PJM DLR Economic Analysis Simulation

To study the economic impact of DLR on a congested line, PJM performed an analysis of a hypothetical DLR project using PJM's 2018 PROMOD Market Efficiency base case.

1. **Congested line in PJM selected**
2. **LineVision generated back-casted DLRs***
3. **PJM ran 2018 PROMOD Market Efficiency base case with adjusted line ratings from back-cased DLRs**

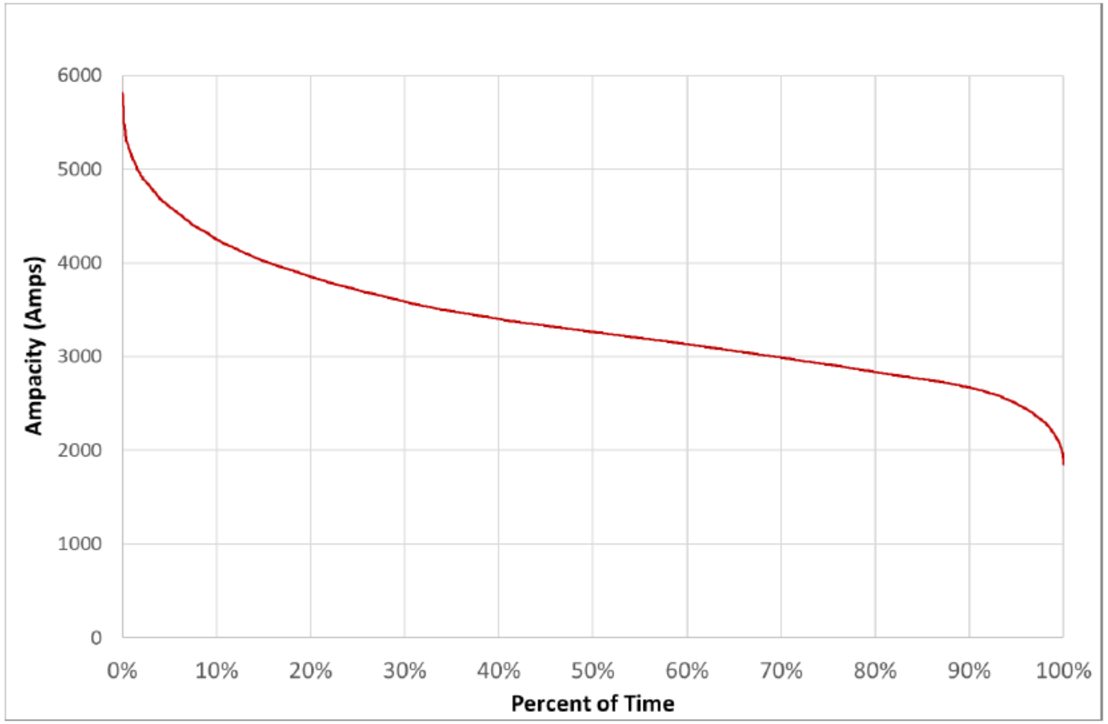
- *DLRs were calculated using historical weather data from six (6) NOAA meteorological stations surrounding the line path, the lowest observed wind speed at each hour (with the accompanying direction) was used for the DRL calculation for each section.



DLR was above the Ambient Adjusted Rating approximately 94% of the time.

Economic Simulation: Inputs

- ABB PROMOD economic forecasting tool used
  - Target line: most thermally congested line in PJM
  - Back-casted DLR ratings from NOAA historic weather data
  - Hourly security-constrained dispatch for one year
- PJM Market Efficiency 2018 AS-IS Base Case was used: 2018 Summer Peak MMWG transmission system topology; 2018 PJM Load Forecast; PJM queue generation as of October 2017



Economic Simulation: Assumptions

- A DLR technology will only bring benefit when the transmission conductor is the most thermally limited element in the line – assumed acceleration of an equipment rating upgrade project.
- DLR installations should be prioritized on the most heavily congested areas of a power system.
- Ambient air temperatures were computed as average of the six stations.
- Wind speed and direction treated more conservatively by adopting the lowest observed wind speed at each hour (with the accompanying direction).
- Solar irradiance calculated using a conservative approximation - zero cloud coverage and was calculated for each hour of the day based the sun’s position in the sky above the Target Line path.

Economic Simulation: Process

- 2 PROMOD simulations were employed:
  - A Base simulation using planning ratings 2800 MVA normal and 3500 MVA emergency for the 500 kV Target Line;
  - A PROMOD DLR simulation using dynamic hourly ratings

Economic Simulation: Results

Total Annual Congestion			
Circuit	**Base Case**	**DLR Case**	**Congestion Savings**
Target Line 500 kV	$ (11,118,805)		$ 11,118,805
Target Line Terminus Substation Transformer 500/230 kV	$ (10,011,856)	$ (9,780,911)	$ 230,945
Downstream Line #1 230 kV	$ (20,386,483)	$ (22,773,039)	$ (2,386,555)
Downstream Line #2 to Downstream Reactor 230 kV	$ (13,491,444)	$ (16,180,653)	$ (2,689,209)
Downstream Reactor - Target Line Terminus 230 kV	$ (1,145,829)	$ (2,492,945)	$ (1,347,115)
Downstream Line #3 - Target Line Origin 230 kV	$ (2,867,503)	$ (3,336,319)	$ (468,816)
Downstream Line #4 230 kV	$ (19,570,723)	$ (19,824,341)	$ (253,619)
			$ 4,204,436

- Assuming $500k installation cost: 8.4:1 benefit to cost ratio for one year
- All congestion on Target Line eliminated
- Residual congestion pushed “downstream” – consistent with other transmission upgrade projects

Additional Considerations of Dynamic Line Ratings

- Market Alignment
  - 24-48 hr. forecasted ratings are needed for inclusion in the Day Ahead market.
  - Contemplating impacts on the FTR market.
- Specifications set by PJM and /or the asset owner on forecasting and line loading.
- DLR technologies are rapidly deployable. Potential for these projects to serve both long-term and short-term transmission needs.
- Posting ratings on pjm.com
- Beyond economic savings, additional advantages of DLR include:
  - Asset health monitoring
  - Detection of icing / galloping
  - Better protection against excessive conductor sag

October ETF Discussion on DLR

- Input presentations from the DLR community
- PJM to review impacts of DLR on:
  - Business areas at PJM
  - Manuals / Governing Documents

Facilitator:
Michele Greening,
Michele.Greening@pjm.com

Secretary:
Natasha Holter,
Natasha.Holter@pjm.com

Presenter:
Shaun Murphy, shaun.murphy@pjm.com

Dynamic Line Ratings

Member Hotline

(610) 666 – 8980

(866) 400 – 8980

custsvc@pjm.com

