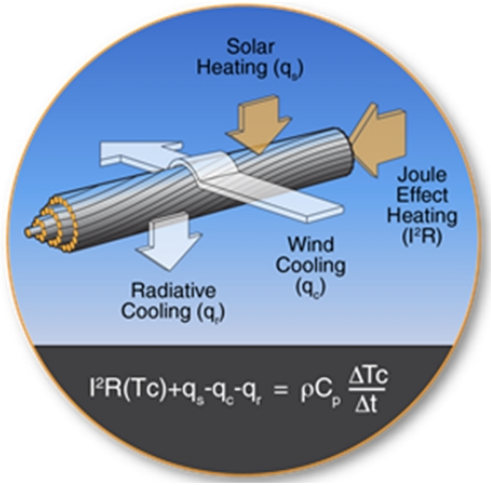
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

E05 - Enhancing Reliable and Accurate Weather Forecasts for Increased Grid Reliability for Wind with Dynamic Line Rating (DLR)



Mitigate Market Barriers - Grid Integration

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August 3, 2021

FY21 Peer Review - Project Overview

Project Summary:

- Previous research and pilot demonstrations has shown that the electric current carrying capacity (ampacity) of transmission lines could be increased by as much as 30-40% by using hourly/daily weather forecasts for Dynamic Line Ratings (DLR). The electric utility industry has indicated that even a 1-2% increase in transmission capacity would be beneficial during capacity constrained periods.
- This project seeks to further the application of INL's Operational and Strategic Implementation of Dynamic Line Rating for Optimized Wind Energy Generation Integration and NOAA's High-Resolution Rapid Refresh (HRRR) mesoscale forecast models to DLR.
- **Key project partners**: INL, NOAA, WindSim, NorthRenew, EPRI, BPA, NYPA, National Grid US, FERC, and NERC.

Project Objective(s) 2019-2020:

- Develop Uncertainty Assessment Tools
  - DLR forecasting application capable of providing intra-day, next-day, and longer-term estimates.
- Characterization & Assessment of Forecasts
  - Certainty studies of DLR across the continental United States to characterize and improve the quantification of uncertainty of forecasts of temperature, low-level winds, and solar radiation.
- Expand and Apply Methodology U.S.-wide
  - Use DLR derived HRRR (High-Resolution Rapid Refresh) forecasts to validate and expand to additional interconnects within the continental United States

Overall Project Objectives (life of project):

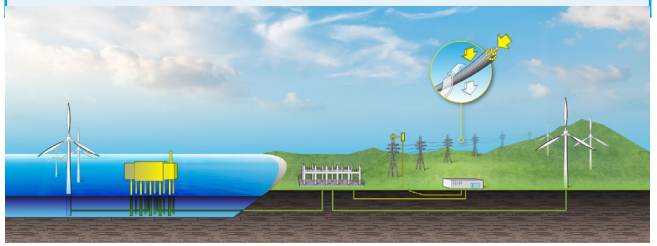
- Increase the Utilization of Existing Transmission and Distribution Infrastructure through the Operational and Strategic Implementation of Dynamic Line Ratings for Optimized Wind Energy Generation Integration

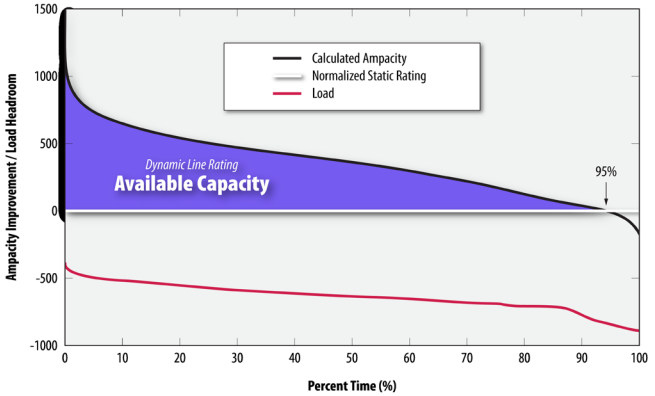
Project Start Year: 2019
Expected Completion Year: FY22
Total expected duration: 3 years

FY19 - FY20 Budget: $600,000

Key Project Personnel: **INL:** Jake Gentle (PI), A. Abboud, J. Lehmer, T. Philips, B. Starks, M. Stapel-Kalat; **NOAA:** K. Fenton, M. Wandishin.

Key DOE Personnel: Jian Fu





Project Impact

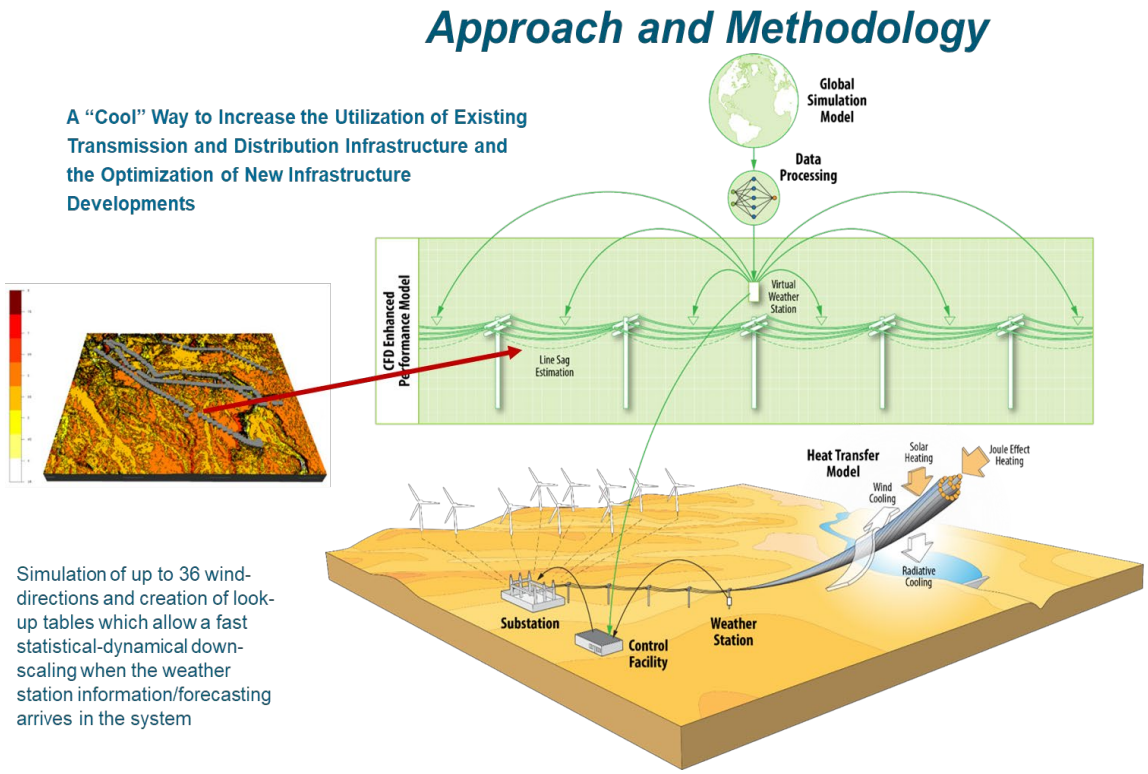
- **Overcome obstacles faced by promising technologies that are capable of:**
  - Enabling innovations in US wind systems
  - Accelerating the deployment of wind generation
- **Provide technology solutions for:**
  - Enhanced integration of renewable energy sources
  - Improved transmission system utilization and efficiency
- **Address challenges of integrating DLR technologies, including:**
  - Uncertainties regarding DLR risk, reliability, operational impact, and net economic benefits
  - Lack of reliable sources for weather forecasting methodologies and data availability

Project Partners Impacted:

Program Performance – Scope, Schedule, Execution

Scope:

- **Task 1:** Establish methodology for uncertainty characterization of forecast models for DLR – Q1FY20
- **Task 2:** Implementation of Uncertainty Characterization
- **Task 3:** Characterize Potential Improvements to Efficiency, Risk Reduction, and Sustainability of the Transmission System for Wind Integration
- **Task 4:** Dissemination of DLR + Forecast methodology and results

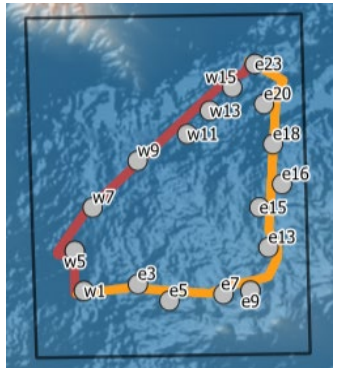


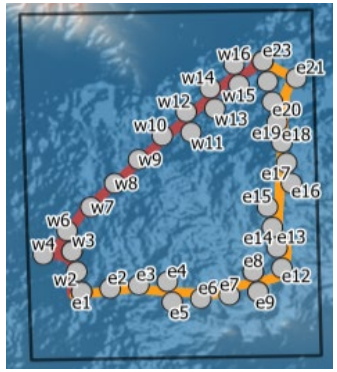
Schedule: Milestone Summary

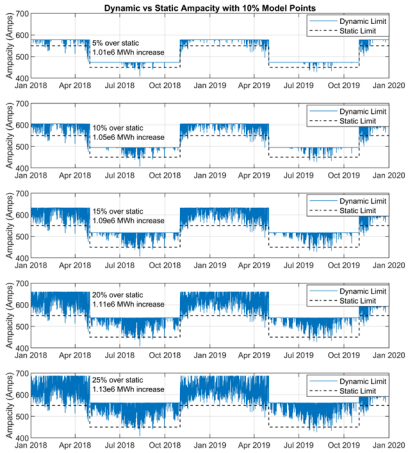
Milestone	Lab	Percentage of completion	Due Date	Completion Date
FY19 Q4: ANNUAL MILESTONE – By 09/30/2019, INL will initiate the identification and development of the methodology to be used in quantifying the HRRR with the variables DLR requires.	INL	100%	*09/30/2019*	*09/30/2019*
FY20 Q1: PROGRESS MILESTONE – By 12/31/2019, INL will identify and gather available information from the transmission congestion database from DOE OE, the Wind Market Report, WFIP2 and EIA for curtailments. INL and NOAA will incorporate the ingestion of this data into the GLASS and HRRR platforms. Identification and development of the methodology to be used in quantifying the HRRR will be completed.	INL	100%	12/31/2019	12/31/2019
FY20 Q2: PROGRESS MILESTONE – By 03/31/2020, INL will establish performance bounds based on initial HRRR model performance results using local observations within the WECC territory	INL	100%	03/31/2020	03/31/2020
FY20 Q3: PROGRESS MILESTONE – By 06/30/2020, INL will identify WECC Proxy lines and look at congestion, weather data, and calculate potential DLR increases using NOAA HRRR data and any available local observation data. Grid fault environments will be tested with and without forecasted DLR impact.	INL	100%	06/30/2020	06/30/2020
FY20 Q4: ANNUAL MILESTONE – By 09/30/2020, INL will support NOAA to provide status update to ASRE Science Council, attend and present at IEEE Overhead Lines Subcommittee [IEEE 738] meetings, IEEE PES GM, CIGRE TAG 4 Working Group - B2.59, ESIG Forecasting Workshop, ESIG Fall Technical Meeting, IEA Task 25 WIW, as well as maintaining full member status within Standards committees and Working Groups (IEEE, IEA, and CIGRE), and continue to follow Regulatory and Policy changes at the NERC and FERC levels.	INL	100%	09/30/2020	09/30/2020
3.3.1 FY21 Q1: In partnership with NorthRenew Energy and Telos Energy, INL will assess a developing wind farm on and around the INL desert site and analyze yearly power generation with Energy Horizons. INL will assess the coupled uncertainty of weather forecast modeling on concurrent cooling through DLR on generator tie line from wind plant to Central Idaho's Snake River Plain regional transmission and distribution networks.	INL	100%	*12/31/2020*	*12/31/2020*
3.3.2 FY21 Q2: INL will summarize the DLR analysis to include 1) the optimized generator tie line sizing from wind farm to main transmission lines using TREAD, and 2) regional impacts to transmission planning. INL will couple the predicted wind power generation with actual and forecasted DLR to determine levels of curtailment with and without DLR. INL will draw on the results of the AC contingency analysis, when coupled with publicly published CapEx for conventional transmission reinforcements for wind integration.	INL	100%	03/31/2021	03/31/2021
3.3.3 FY21 Q3: In partnership with NOAA, INL will use observational weather data and forecasted mesoscale data from the BPA study region to determine concurrent cooling effects of DLR coupling across multiple operational wind farms and multiple transmission line paths.	INL	85%	06/30/2020	
3.3.4 FY21 Q4: INL will use the actual and forecasted DLR capacities from the BPA region to couple with available/published wind farm power generation data to assess curtailment with and without DLR including potential revenue calculations. INL will then examine the curtailment with respect to the existing regional transmission lines and the latest proposed lines within the BPA service territory.	INL	50%	09/30/2021	
1.3.1 FY21 Q4: Initiate the identification of sites for study in the eastern interconnect focusing specifically on offshore wind interconnection requests.	INL	50%	09/30/2021	
4.3.1 FY21 Q4 [Stretch]: INL will facilitate a DLR Workshop in FY21 and provide presentations via an updated INL website (updates from 2017 DLR Workshop).		0%	09/30/2021	

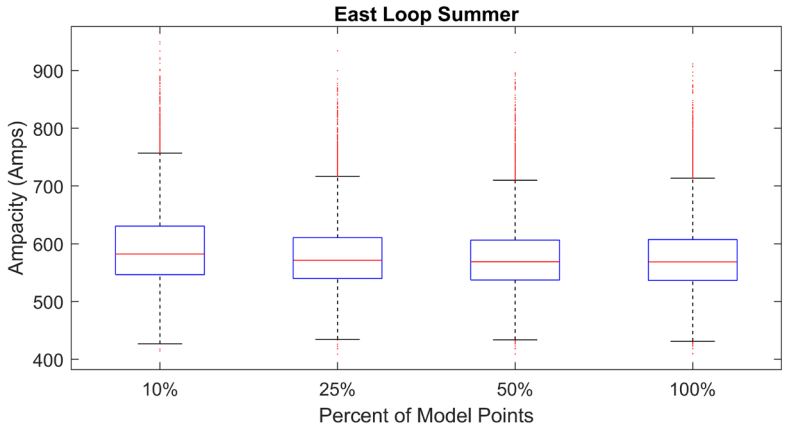
Accomplishment and Highlights - INL Transmission

- **Use-case testing in simple system**
  - Ampacity clipping to 5-10-15-20-25% above static
    - Calculate potential revenue based on MWh
    - Study risk by feeding forecasted ampacity through actual observed conditions to see how often max conductor temperature exceeded
  - Test number of weather stations vs. ampacity accuracy
    - Initially used all HRRR points and decrease total used
  - 40 HRRR points, 10 NOAA MesoNet weather stations
  - Based on spatial sampling determined ~6km spacing is best



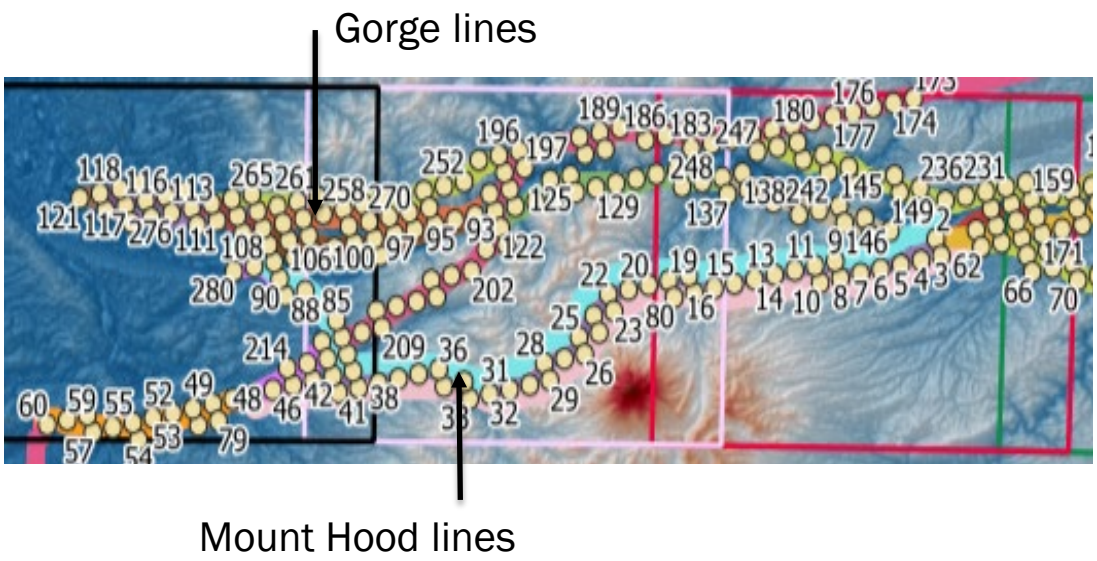


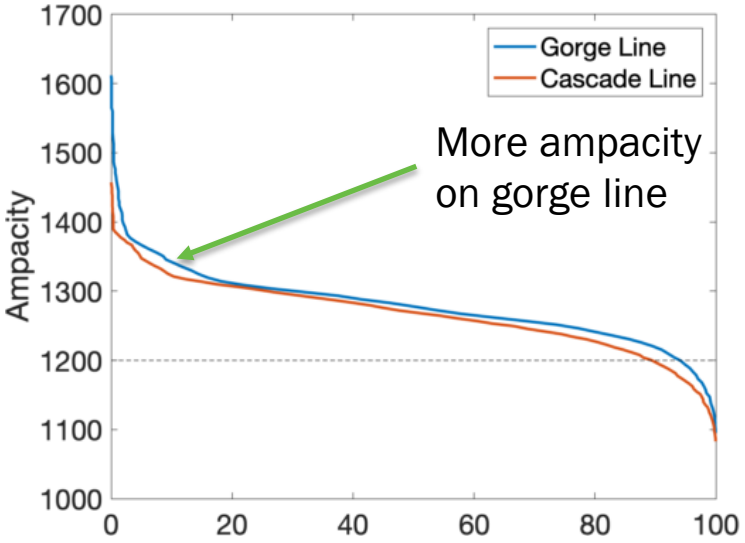




Accomplishment and Highlights - BPA Site

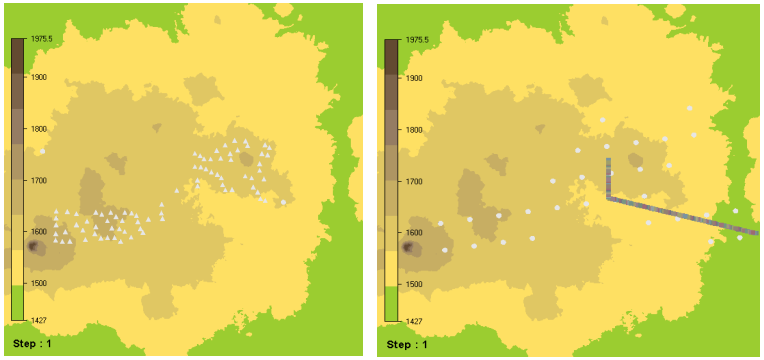
- Use Case Testing in Large Area Site
  - 60km x 220km area in Columbia Gorge with 20+ lines/3000+ midpoints
  - Study transmission of wind generation east of cascades to western side
  - Potential to further examine cascade expansion line (southern path) and previous curtailment
  - Looking at using HRRR vs only those nearby reliable weather stations
  - Non-NOAA (or INL) weather stations in region:
    - had to pull Mesonet data and apply standards to bad data
      - 280 HRRR points
      - 75 WS after parsing

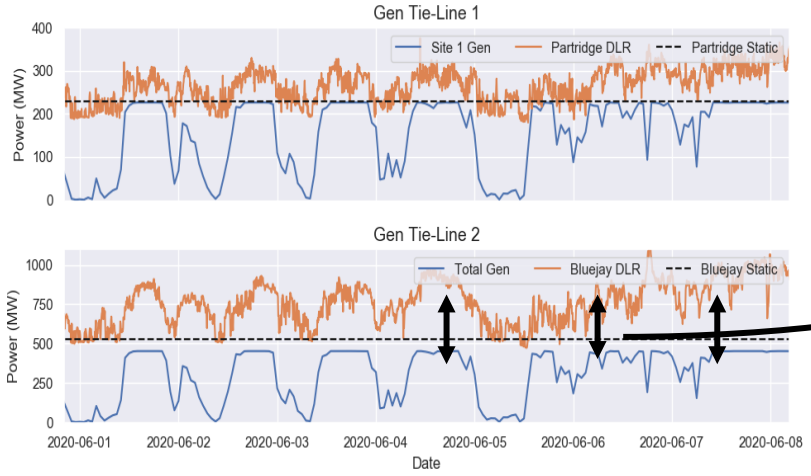


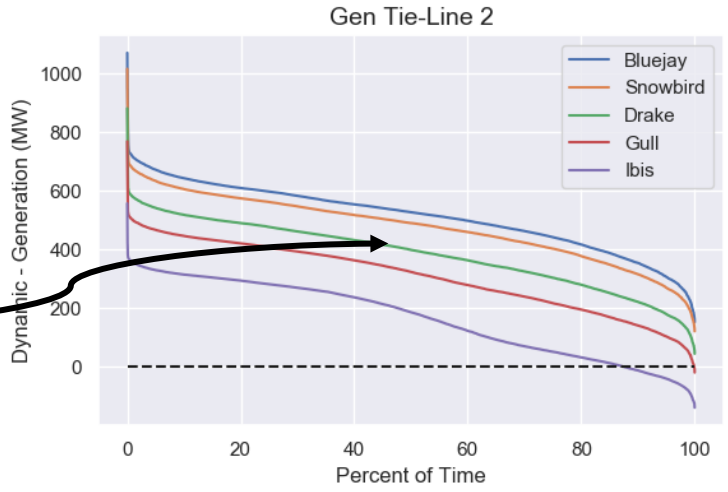


Accomplishment and Highlights - NorthRenew Wind Plant w/Concurrent Cooling & Transmission Routing

- Model DLR on wind plant generator-tie lines
- Model wind power generation at site
- Comparison of HRRR forecast to weather observations for error assessment
- Calculate benefit of large difference between the power generation and the DLR capacity
- Quantify expansion possibility for Wind Farm
  - Static rated Bluejay to provide 450 MW maximum capacity
  - DLR rated Bluejay has *additional* 233 MW capacity 99% of the time







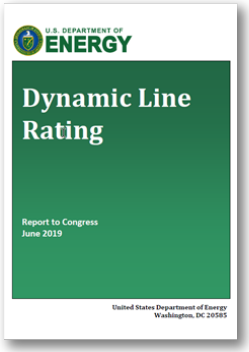
Execution: Top Five Notable Publications

- Coupling computational fluid dynamics with the high resolution rapid refresh model for forecasting dynamic line ratings
  - *Electric Power Systems Research* 170 (2019): 326-337.
- Using Computational Fluid Dynamics to Assess Dynamic Line Ratings in Southern Idaho
  - Presented at CIGRE Grid of the Future Symposium, available online
- Improvement of Transmission Line Ampacity Utilization by Weather-Based Dynamic Line Rating
  - IEEE Transactions on Power Delivery 33, no. 4
- Using Computational Fluid Dynamics of Wind Simulations Coupled with Weather Data to Predict Dynamic Line Ratings
  - *IEEE Transactions on Power Delivery*
- Forecasting Dynamic Thermal Line Ratings
  - CIGRE working group B2.59 Technical Brochure

Stakeholder Engagement & Information Sharing

(3) Reports to Congress

(1) Published 2019
(1) Published 2020
(1) Under development 2021



Standards

Lead Author in IEEE and CIGRE standard working groups and task forces. PI is one of two U.S. Delegates on CIGRE Working Group - B2.59: *Forecasting Variable Line Ratings* and - B2.79: *Enhancing Overhead Line Rating Prediction by Improving Weather Parameters Measurements*

Publications/Awards

10+ peer reviewed journal articles, **25+** conference proceedings, **50+** invited presentations, Best Conference Paper on Markets, Economics, and Planning (IEEE PES GM), IEEE Transactions on Power Delivery (2018, 2019, 2020); Two-time R&D 100 Award Finalist.

Integration with NOAA

Initiated algorithm development for line rating forecasts with higher fidelity and accuracy using NOAA's High-Resolution Rapid Refresh (HRRR) atmospheric model.

Commercialization

(3) Copyrights asserted, DOE Energy I-Corps (2x), DOE Technology Commercialization Fund (completed), CRADAs, active licensees for real-time GLASS, FERC testimonies and WATT Coalition strategies, Workshops and Webinars, WindSim Power US headquartered company launch.

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Latest Stakeholder Engagement & Information Sharing

Type of Outreach	Title	Date	Source
Conference Paper	Sensitivity of Line Ratings for High Temperature Conductors	9/3/2020	CIGRE 2020 e-session
EPRI Presentation	Forecast Modeling for Dynamic Line Rating	8/1/2020	EPRI Task Force Meeting
Conference Paper	Sensitivity of Line Ratings for High Temperature Conductors Rev 1	08/15/2021	CIGRE 2021 session
Conference Presentation	Concurrent Cooling considerations for a Gen-tie line	06/7/2021	Clean Power 2021
Conference Poster	Dynamic Line Rating Testbed Study Using Weather Forecasting	06/7/2021	Clean Power 2021
Conference Poster	Feasibility and Prospects of the High Resolution Rapid Refresh Model For Dynamic Line Rating	06/7/2021	Clean Power 2021
EPRI Presentation	Forecast Modeling for Dynamic Line Rating	05/25/2021	Session on Overhead Conductors
MISO Presentation	Overview of Forecasts for Dynamic Line Rating	11/16/2021	MISO 2021 Meeting

Project Performance - Upcoming Activities

- Submission of conference papers to GOTF 2021
- Expansion of EPRI project to perform start-to-finish DLR field trial with Bonneville Power Administration
- Publishing of 2021 GETs Report to Congress
- 1.3.1 FY21 Q4: Initiate the identification of sites for study in the eastern interconnect focusing specifically on offshore wind interconnection requests
- 2.3.1 FY22 Q1: Initial forecast to observation comparison and DLR analysis of eastern connect region of interest.
- 4.3.2 FY22 Q2: INL and NOAA will complete a Cost/Benefit Summary report and publish as an INL Technical Report and make available on DOE WETO and INL websites for the Snake River Plain and Columbia Gorge Regions.
- 4.3.3 FY22 Q3: INL and NOAA will complete a technical report detailing the eastern region study involving concurrent cooling associated with offshore wind, contrasting and comparing the western and eastern regional trends
- 3.3.3 FY21 Q3: In partnership with NOAA, INL will use observational weather data and forecasted mesoscale data from the BPA study region to determine concurrent cooling effects of DLR coupling across multiple operational wind farms and multiple transmission line paths.