DOE Office of Electricity TRAC

Peer Review

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

PROJECT SUMMARY

Demonstration of Advanced Monitoring and Data Analytics of Power Transmission Lines

ORNL, LineVision, and Xcel Energy outfitted 3 transmission lines with advanced non-contact sensors (EMF and LiDAR) to monitor for 12 months and collect data from conductors to determine power market efficiencies gained from Dynamic Line Ratings (DLR) as well as planning efficiencies achieved from novel conductor health assessments.

PRINCIPAL INVESTIGATORS

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WEBSITE

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The Numbers

DOE PROGRAM OFFICE:
OE – Transformer Resilience and Advanced Components (TRAC)

FUNDING OPPORTUNITY:
AOP

LOCATIONS:
Minnesota, Wisconsin, Colorado

PROJECT TERM:
01/01/2021 to 06/30/2022

PROJECT STATUS:
Incomplete, Ongoing

AWARD AMOUNT (DOE CONTRIBUTION):
$500,000

AWARDEE CONTRIBUTION (COST SHARE):
$350,000 LineVision Subcontract

Executive Summary

- ORNL, Xcel Energy, and LineVision have been engaged in a project to demonstrate Dynamic Line Ratings (DLR) and Conductor Asset Health assessments with non-contact sensor technology.
- Sensors were installed on lines in MN, WI, and CO.
- Average DLR exceeded static reference ratings by 9-33% in winter months and 26-36% in summer months at the monitored sites; Available on monitored lines over 85% of the time.
- The impact to Xcel Energy, and utilities in general, is more transmission capacity available today to integrate renewable energy via a cost-effective technology. Utilizing DLR will provide a significant increase in capacity and greater flexibility in operations,
- Ongoing analysis to evaluate the impacts of Dynamic Line Rating with power flow simulations on Xcel lines in MISO.
- Conductor Asset Health reports show that monitored conductors have not experienced significant annealing and not lost tensile strength, but identified sag discrepancies warranting investigation.

Innovation Update

Non-Contact LiDAR & EMF Sensor Technologies

Patented Technology:

> Electromagnetic Field (EMF) Power Flow Monitoring

> LiDAR Conductor Position Monitoring

Scanning LiDAR:

> Continuously measures conductor position

> Full catenary shape determined and conductor sag & blowout calculated

Simplified Installations

> No outages

> No live-line work

Industry Best Accuracy & Analytics

> Data on all conductor phases

> Any tower, any voltage, any conductor

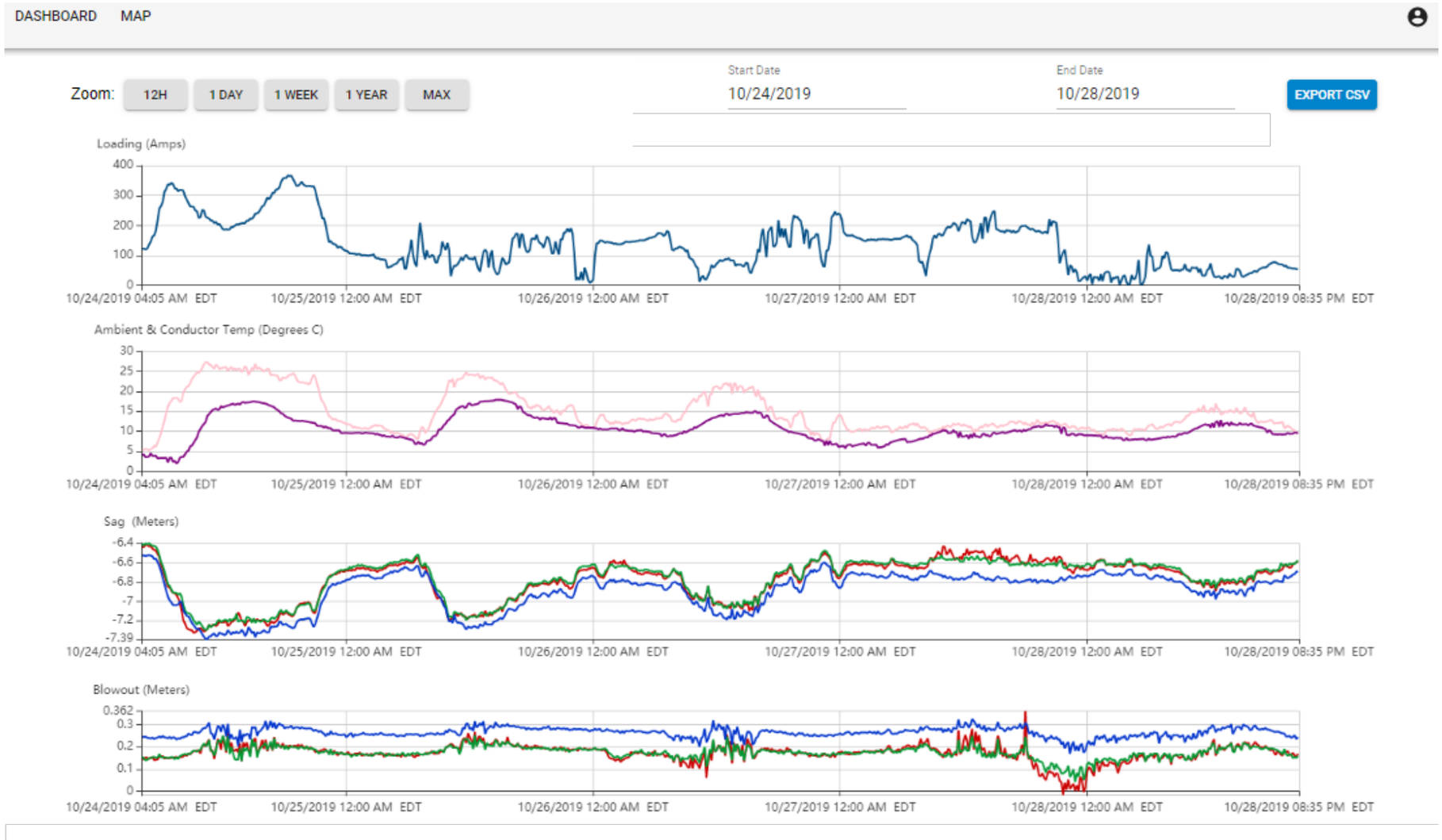
> IEEE & CIGRE standards based

LineAware

Real-time field verified information and alerts on conductor motion allows operators and risk managers to protect asset health, system reliability and public safety.

Output:

- Each phase conductor sag
- Each phase conductor blowout
- Line loading, current
- Icing & galloping alerts
- Anomalous motion alerts
- Local ambient weather conditions



LineRate

Increases the transfer capacity on existing transmission lines with Dynamic Line Ratings.

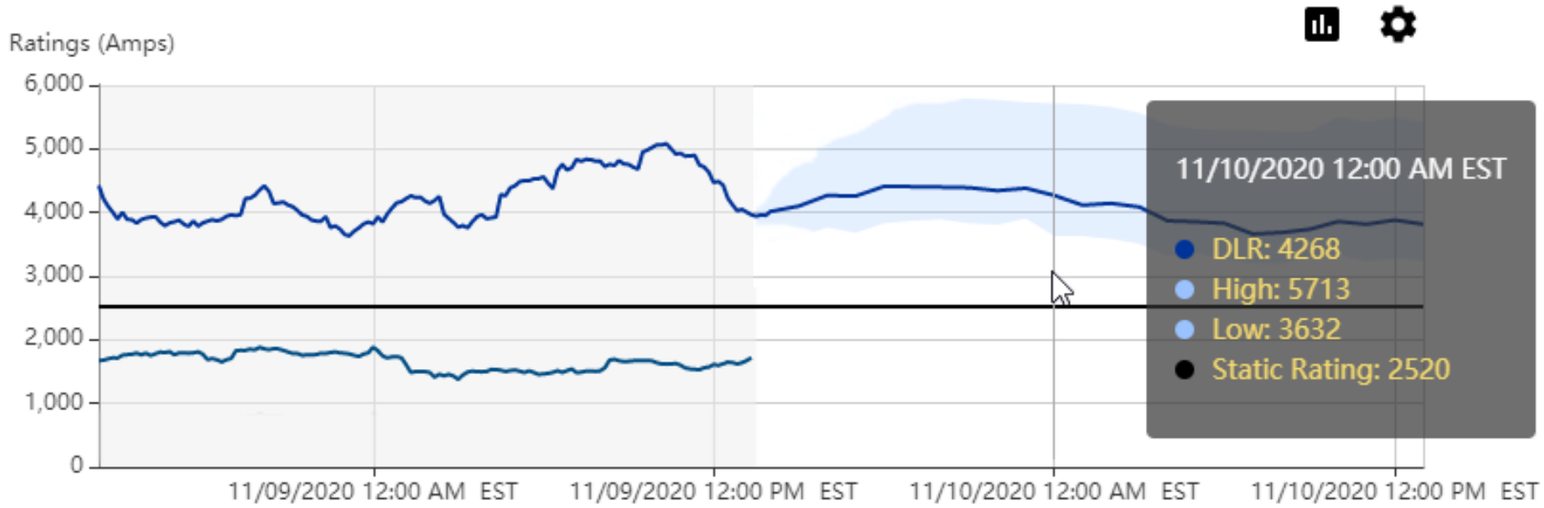
Output:

› Dynamic Line Rating

› Conductor temperature

› Forecasted line ratings, time-configurable

› Emergency ratings (STE, LTE, Load-Dump)



FERC Order No. 881 Requires:

› Transmission providers implement ambient adjusted ratings on the transmission lines over which they provide transmission service that are impacted by air temperatures.

› RTOs and ISOs are required to implement the systems and procedures necessary to allow electronically updated transmission line ratings least hourly.

› FERC will continue to explore the implementation of Dynamic Line Ratings in a new docket AD22-5-000.

LineHealth

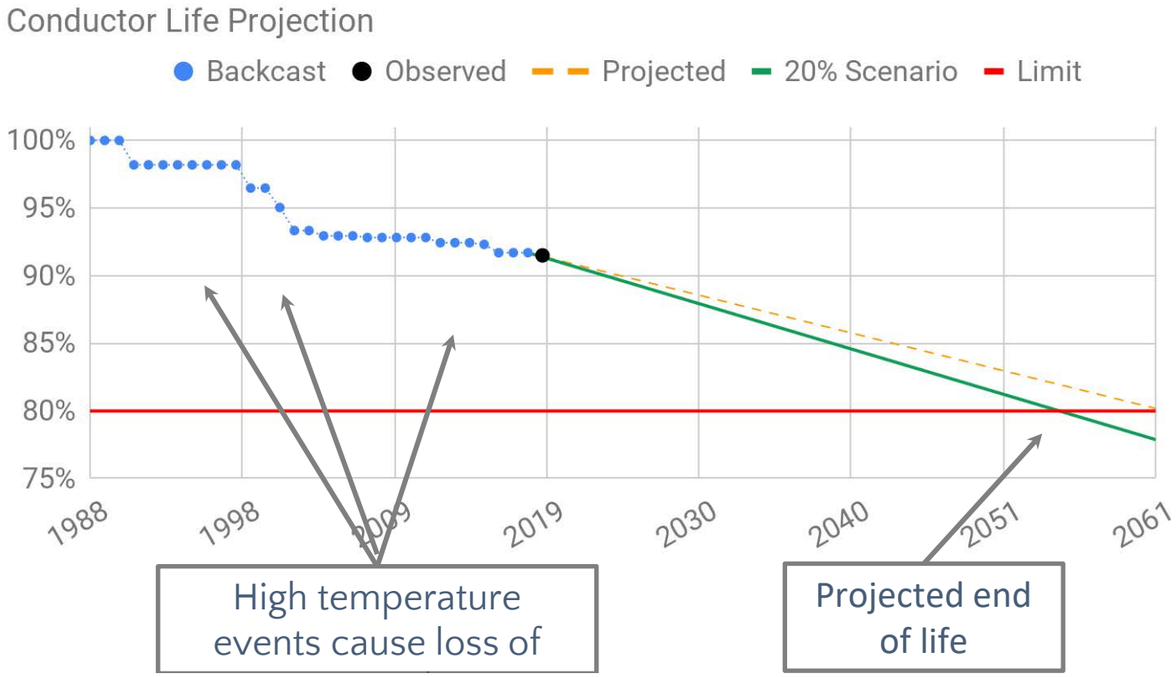
Create a conductor digital twin and prioritize the repair and replacement of lines that are most critical based on the module's estimation of remaining conductor life.

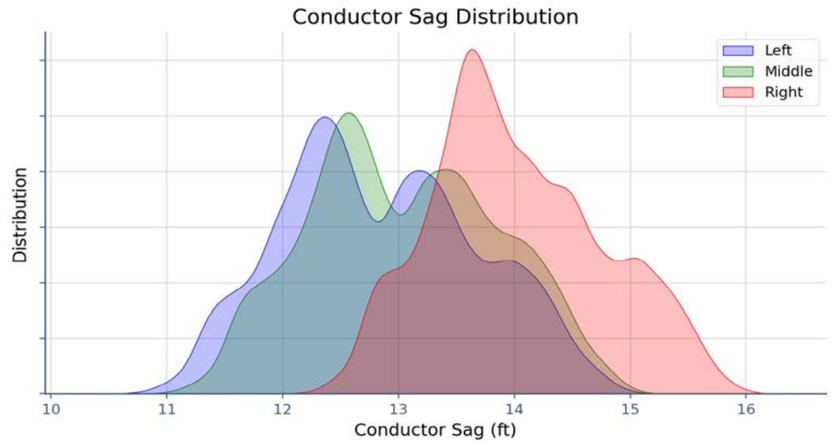
Inputs:

- Historical SCADA
- Historical weather data
- Engineering design information
- LineVision sensor measurements

Output:

- Thermal aging analysis and loss of tensile strength from annealing
- Projected conductor end of life
- Conductor elongation damage evaluation: designed vs actual sag
- Operating limit recharacterization
- Rated breaking strength evaluation
- Sag discrepancies
- Galloping & icing event analysis





Dynamic Line Ratings – MN & WI

DLR to Static Line Rating Comparison

Line	Winter Static Rating	Average Winter Dynamic Rating	% Increase	Summer Static Rating	Average Summer Dynamic Rating	% Increase
0817/3303 RPO–GMT	1460	1594	9.2%	1076	1451	34.8%
3101 ASK–ECL*	2000	3661	83.0% *	1994	3358	68.4% *

* Line 3101 ASK-ECL is clearance-limited by other spans along the line which are not monitored by LineVision.

Dynamic Line Ratings – CO

DLR-Static Rating Comparison

Line	Winter Static Rating	Average Winter Dynamic Rating	% Increase	Summer Static Rating	Average Summer Dynamic Rating	% Increase
7109 DANI-MSST	3257	4081	25.3%	2868	3715	29.5%
5115 DANI-SRDG	2086	2562	22.8%	1849	2338	26.4%
5113 DANI-MSST	2112	2798	32.5%	1860	2536	36.3%

Asset Health Comparison – Colorado

	Line 5113		Line 5115				Line 7109		
	Site 9b	Site 11b	Site 9b	Site 10	Site 10	Site 11b	Site 8	Site 9a	Site 11a
Maximum Conductor Temperature Calculated	223 F	215 F	111 F	108 F	107 F	109 F	107 F	114 F	114 F
Strength Reduction due to Thermal Annealing	0%	0%	-	0%	0%	-	0%	0%	0%
Sag Increase Observed - Design	0.0 ft (0.0%)	-2.1 ft (-4.2%)	-0.5 ft (-0.4%)	0.7 ft (2.0%)	-2.1 ft (-6.1%)	0.2 ft (0.4%)	0.9 ft (5.5%)	4.8 ft (4.3%)	0.2 ft (0.6%)
Revised Projected Max Operating Temperature	212 F (no change)	212 F (no change)	212 F (no change)	184 F	212 F (no change)	207 F	188 F	142 F	207 F

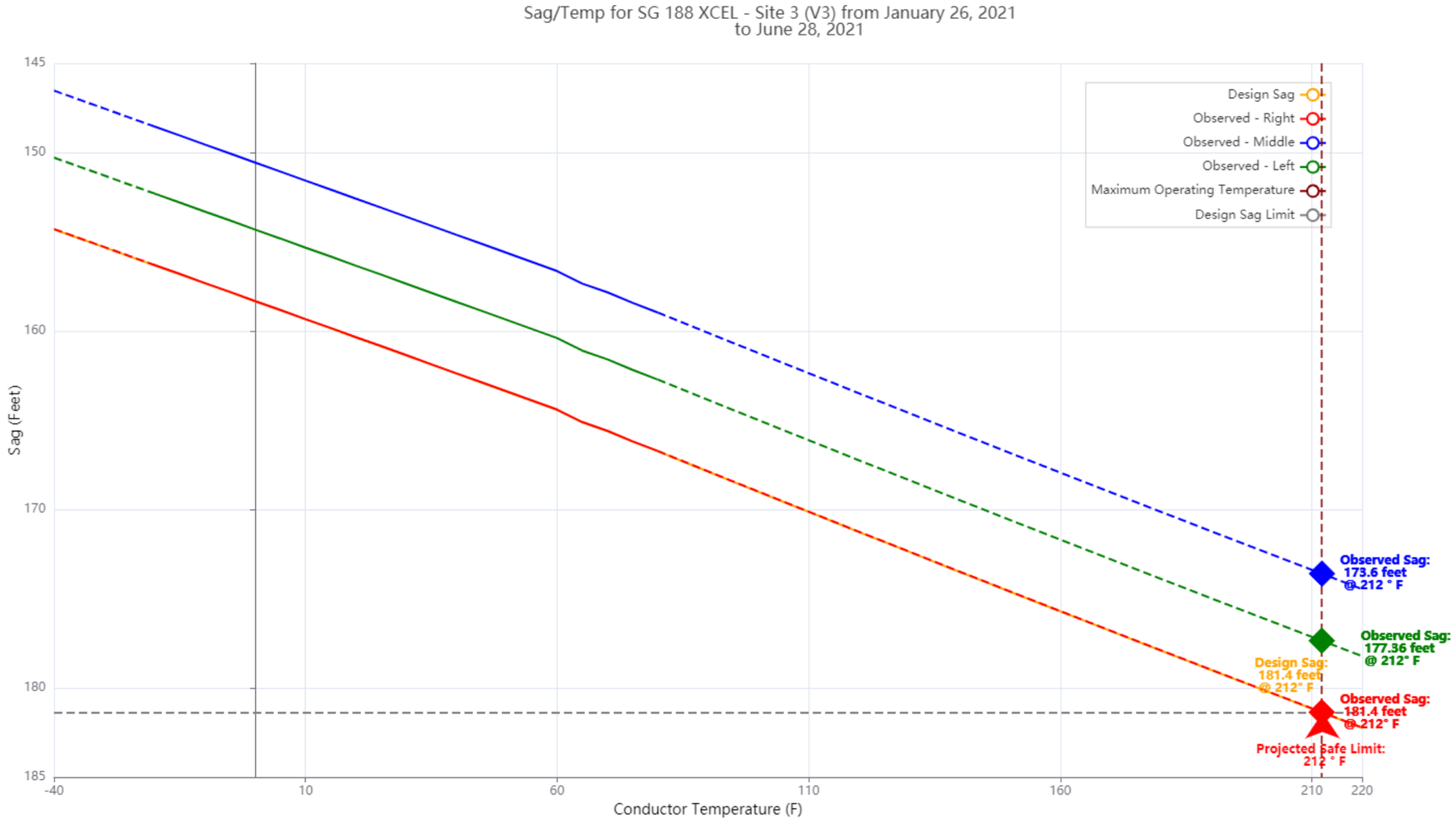
Phase by Phase Sag Discrepancy Observed

Site 3 has a difference in absolute sags

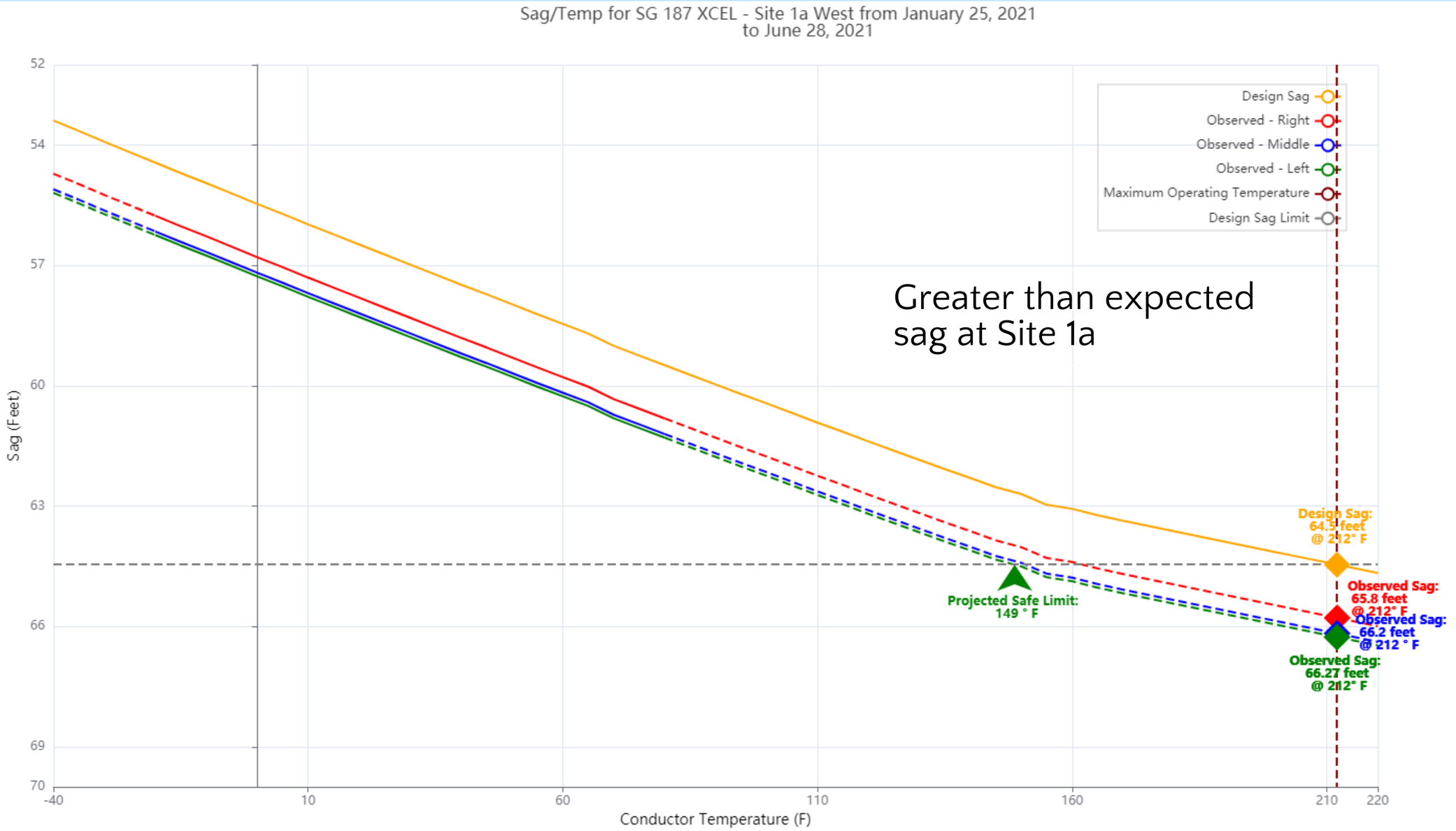
Left Phase
-4.0 ft (-2.2%)

Middle Phase
-7.8 ft (-4.3%)

Right Phase
0 ft (0.0%)

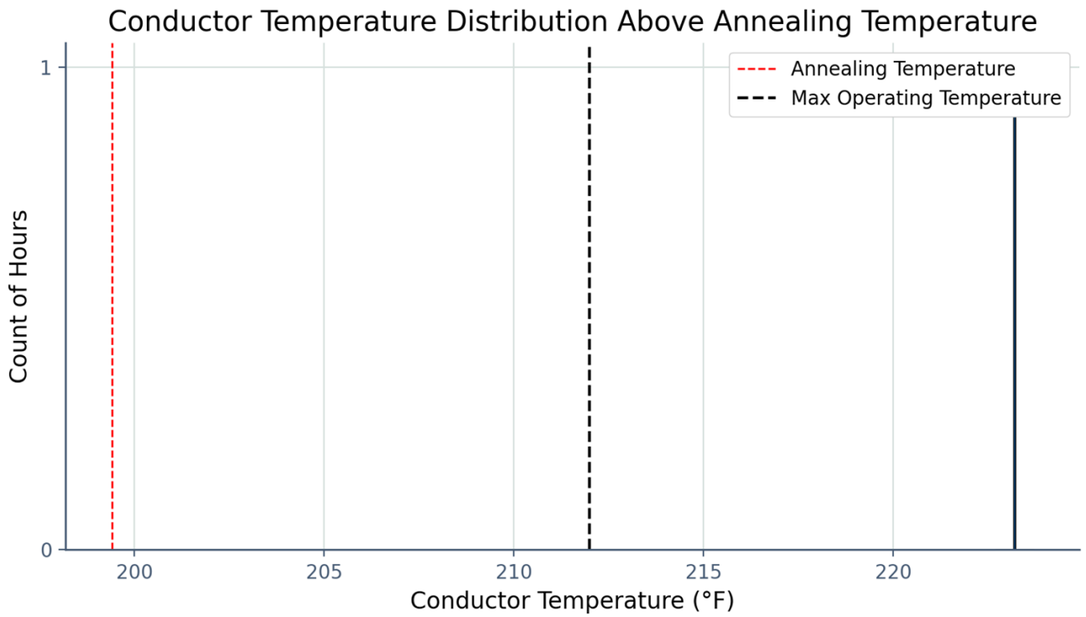


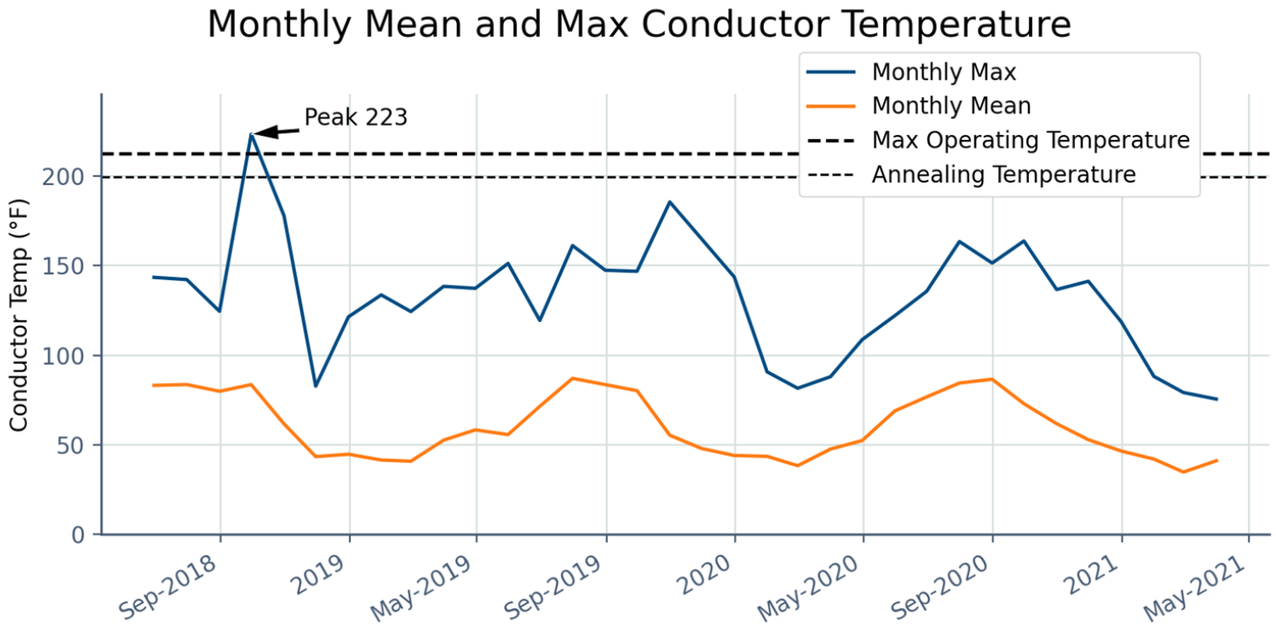
Max Sag Exceeds the Designed Value



Elevated Temperature Detected

Line 5113 conductor temperature has likely exceeded annealing





Annealing Temp	Max Calculated Conductor Temp
200 F (93 C)	223 F (106 C)

DLR and Xcel's Carbon Commitment

Xcel will take a multi-pronged approach to achieving its carbon commitments. Increased transmission capacity in the form of new transmission lines and optimization of existing lines will allow for increased renewable generation and dynamic use of existing assets.

- A National Renewable Energy Laboratory study found that to reach 80% renewable electricity in the United States, a 56%–105% increase in long-distance transmission capacity would be required[1]. Grid enhancing technologies can double the capacity on existing power lines right now.[2] New transmission is needed, but DLR can be strategically leveraged and make immediate impacts.

- In areas where moderate or strong winds are common, the use of a DLR monitoring system can increase the achieved power flow capacity of overhead conductors by 5–25% when compared to an SLR for 80–90% of the time (results vary across different lines and geographic regions)[3].

[1] T. Mai, et al. Renewable electricity futures for the United States IEEE Trans. Sustain. Energy, 5 (2014), pp. 372–378
[2] T. Bruce Tsuchida, Stephanie Ross, and Adam Bigelow, The Brattle Group, "Unlocking the Queue With Grid-Enhancing Technologies," February 1, 2021.
[3] Dynamic Line Rating Systems for Transmission Lines Topical Report (U.S. Department of Energy, April 25, 2014).

Acronyms

DLR = Dynamic Line Rating

SLR = Static Line Rating

EMF = Electromagnetic Field

LiDAR = Light Detection and Ranging

MISO = Midcontinent Independent System Operator

THANK YOU

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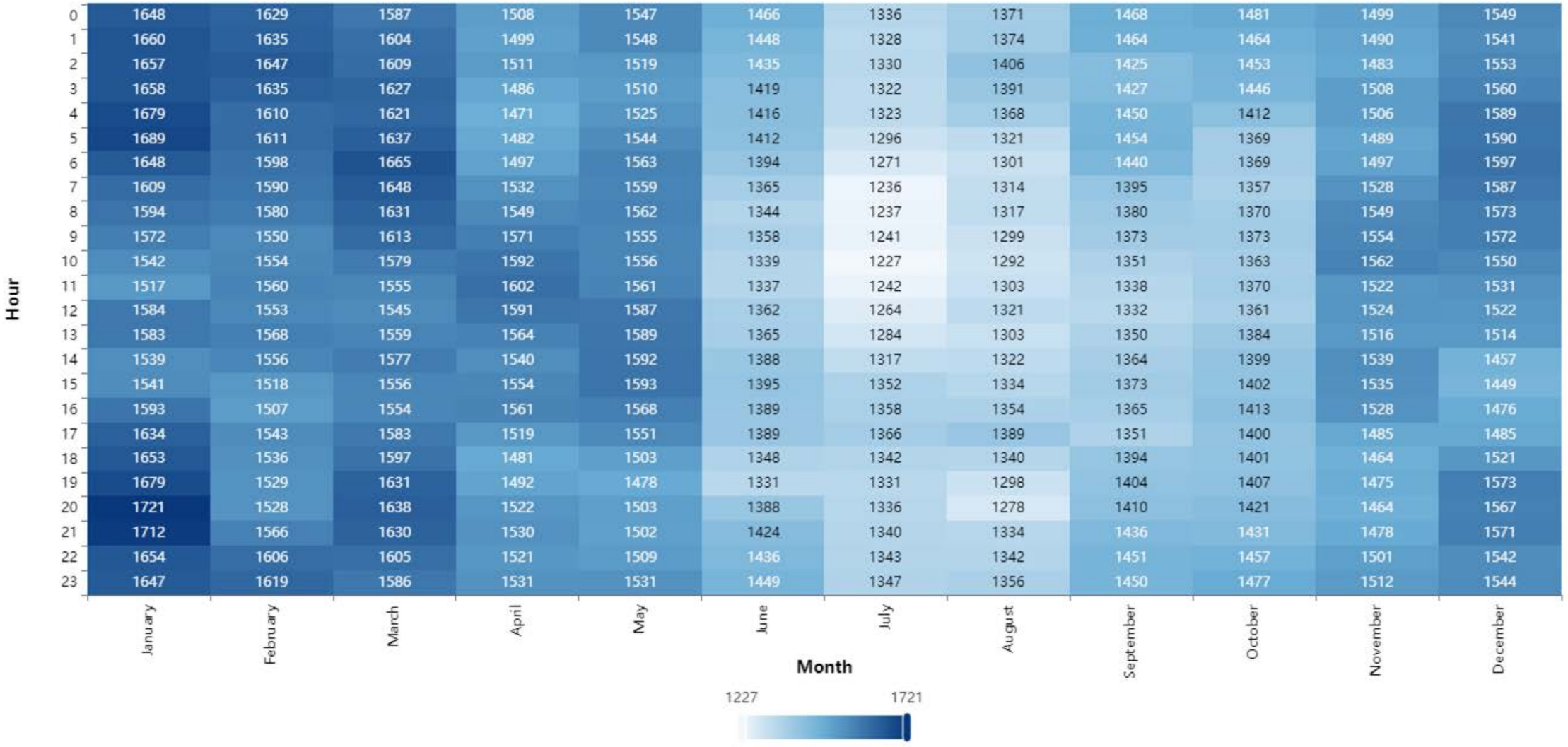
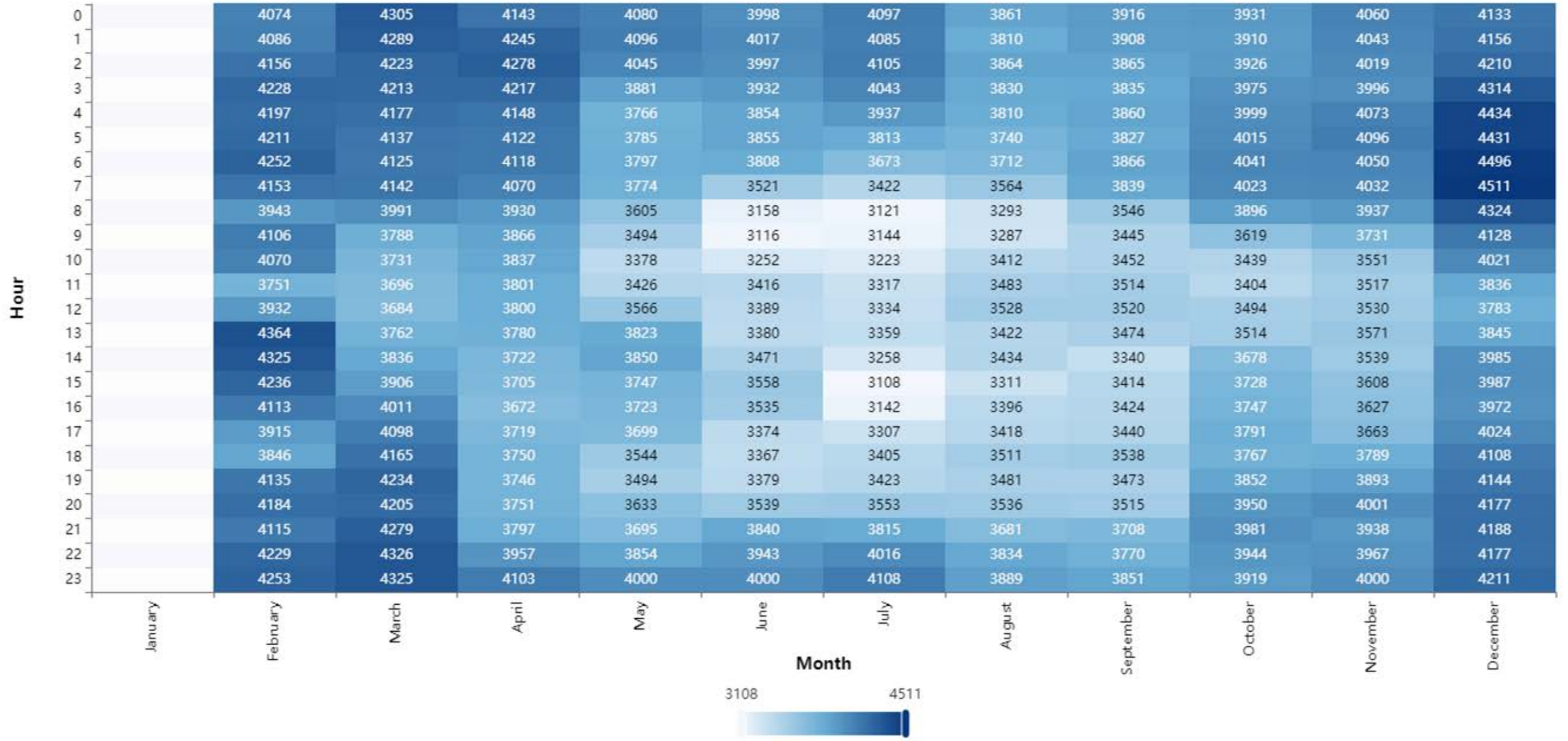
Field Data – Minnesota & Wisconsin

Line 0817/3303 RPO–RRK – DLR Heatmap



Field Data – Colorado

Line 7109 – DLR Heatmap



Field Data – Minnesota & Wisconsin

	Line 0817/3303						Line 3101	
	Site 1a	Site 1b	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Maximum Conductor Temperature Calculated	166F	162F	164 F	147 F	163 F	164 F	170 F	170 F
Strength Reduction due to Thermal Annealing	0%	0%	0%	-	0%	0%	0%	0%
Sag Increase Observed - Design	1.8 ft (2.8%)	-1.1 ft (-2.5%)	0.2 ft (1.3%)	0.0 ft (0.0%)	-0.4 ft (-3.4%)	0.9 ft (6.6%)	2.3 ft (1.3%)	-1.6 ft (-2.4%)
Revised Projected Max Operating Temperature	149 F	198 F (no change)	185 F (from 198 F)	212 F (no change)	212 F (no change)	159 F	184 F	212 F (no change)