

Dynamic Line Rating

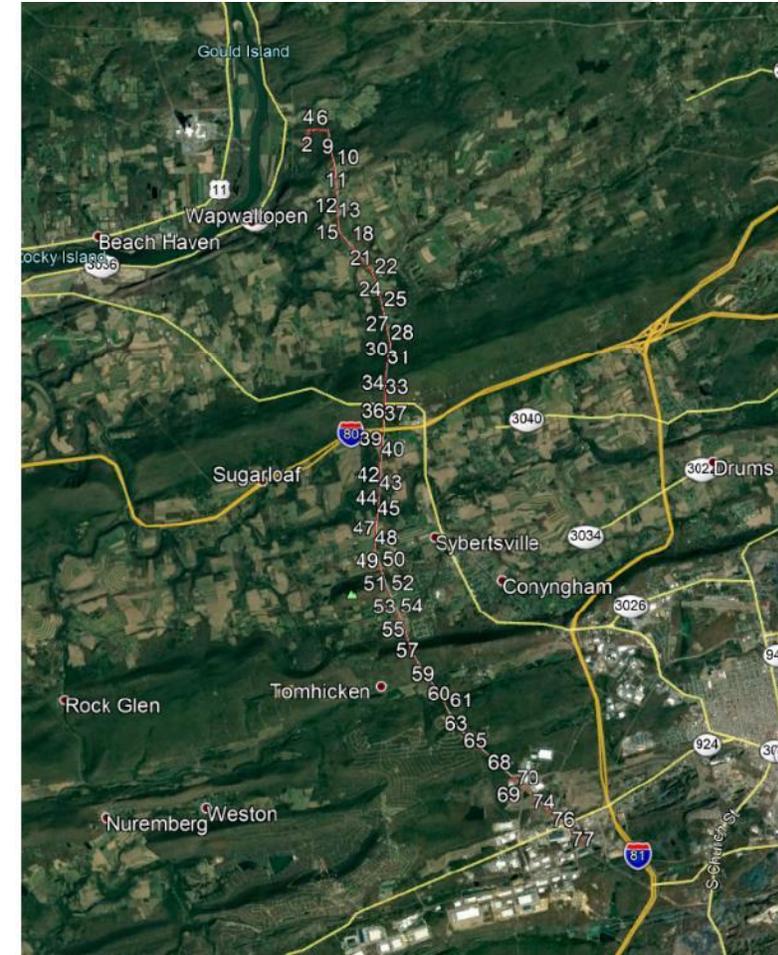
How PPL is lifting congestion costs in the PJM region

Background

\$14.5 Million in annual congestion costs projected in 2025

Harwood to Susquehanna | 230 kV | ACSS | 730 MVA Static

2020/21 RTEP Market Efficiency Window Eligible Energy Market Congestion Drivers* (Posted 03-05-2021)				ME Base Case (Annual Congestion \$million)		ME Base Case (Hours Binding)	
FG#	Constraint	FROM AREA	TO AREA	2025 Simulated Year	2028 Simulated Year	2025 Simulated Year	2028 Simulated Year
ME-1	Kammer North to Natrium 138 kV	AEP	AEP	\$ 2.02	\$ 6.56	69	167
ME-3	Junction to French's Mill 138 kV	APS	APS	\$ 9.18	\$ 11.97	276	301
ME-4	Yukon to AA2-161 Tap 138 kV	APS	APS	\$ 4.36	\$ 5.16	1742	1958
ME-5	Charlottesville to Proffit Rd Del Pt 230 kV	DOM	DOM	\$ 3.76	\$ 4.96	121	124
ME-6	Plymouth Meeting to Whitpain 230 kV	PECO	PECO	\$ 3.33	\$ 4.09	111	101
ME-7	Cumberland to Juniata 230 kV***	PLGRP	PLGRP	\$ 9.00	\$ 6.61	213	179
ME-8	Harwood to Susquehanna 230 kV***	PLGRP	PLGRP	\$ 14.49	\$ 8.69	830	501



Solutions Considered

Reconductor



Double Circuit



Dynamic Line Rating



Time to Implement	2 – 3 Years	3 – 5 Years	Months
Downtime	Extended Outages	Extended Outages	No Outages
Cost	\$0.5 M per mile	\$2 - 3 M per mile	< \$1 M
Est Capacity Benefit	+ 34%	+ 106%	+10 – 30%

What is DLR?

System of line sensors installed to measure conductor and real-time environmental data in order to determine the true capacity and forecasted capacity

❑ Static Line Ratings

Assumes

- Wind speed
- Ambient Temp
- Solar Radiation
- 2 Seasons (Planning)

Conservatively Calculates Ratings

No way to measure field conditions, ensure safe operations, or line health

❑ Dynamic Line Ratings

Measures

- Wind Speed
- Ambient Temp
- Conductor Temp
- Conductor Sag

Accurate Real-Time and Forecasted Ratings

Measures Conductor Health

Perpendicular wind is the key factor to increasing capacity

DLR sensors must accurately measure the actual wind speed that each critical span is experiencing

Wind estimates based on weather station data alone have proven to be inaccurate



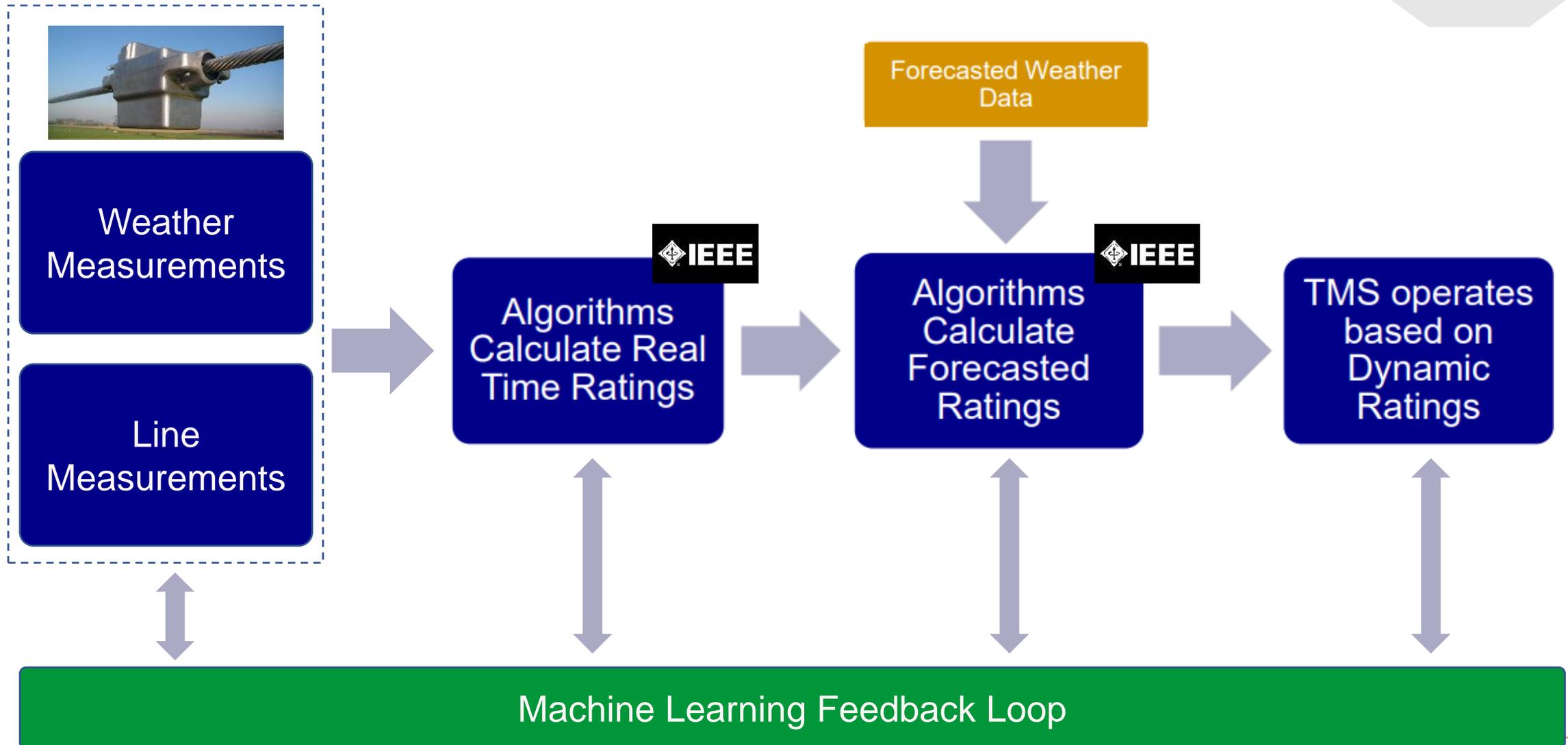
U.S. Department of Energy | April 2014

Operating Conditions	Change in Conditions	Impact on Capacity
Ambient temperature	2 °C decrease	+ 2%
	10 °C decrease	+ 11%
Solar radiation	Cloud shadowing	+/- a few percent
	Total eclipse	+ 18%
Wind	3 ft./s increase, 45° angle	+ 35%
	3 ft./s increase, 90° angle	+ 44%

Source: Navigant Consulting, Inc. (Navigant) analysis; data from (7)

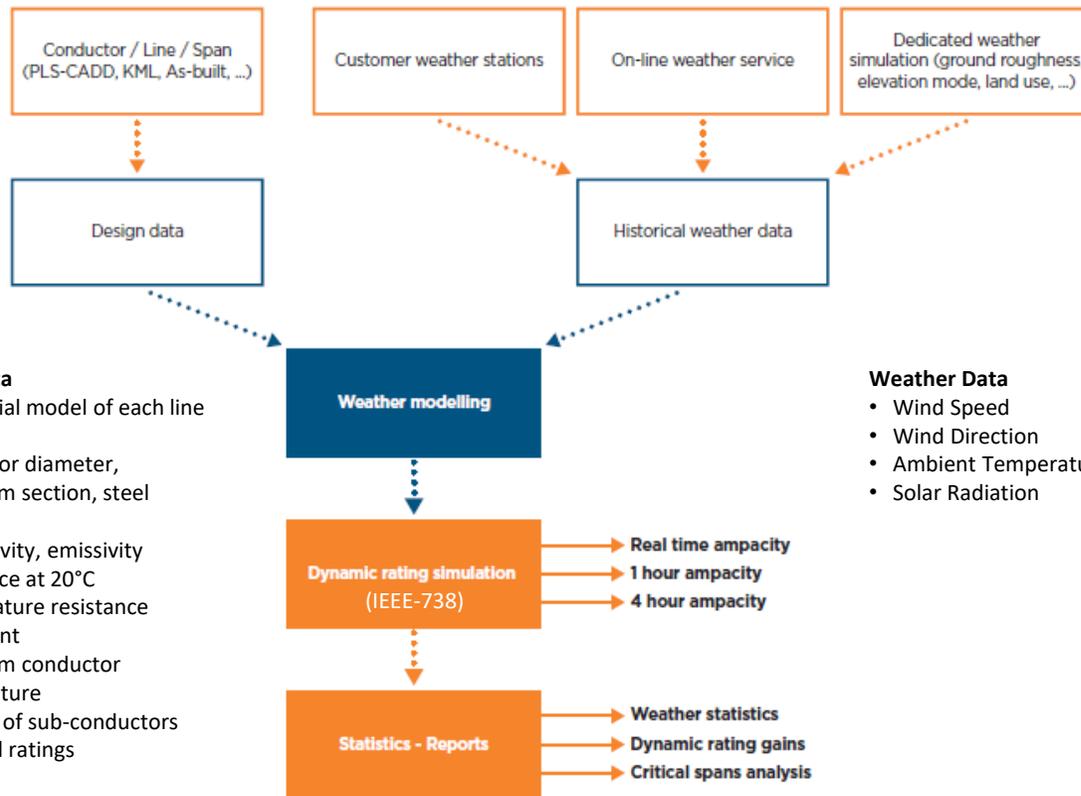
Table 1. Impacts of Changing Operating Conditions on Transmission Line Capacity

Dynamic Line Ratings Process



Planning for DLR

Ampacimon DLR Simulations



Design Data

- Geospatial model of each line span
- Conductor diameter, aluminum section, steel section
- Absorptivity, emissivity
- Resistance at 20°C
- Temperature resistance coefficient
- Maximum conductor temperature
- Number of sub-conductors
- Seasonal ratings

Weather Data

- Wind Speed
- Wind Direction
- Ambient Temperature
- Solar Radiation

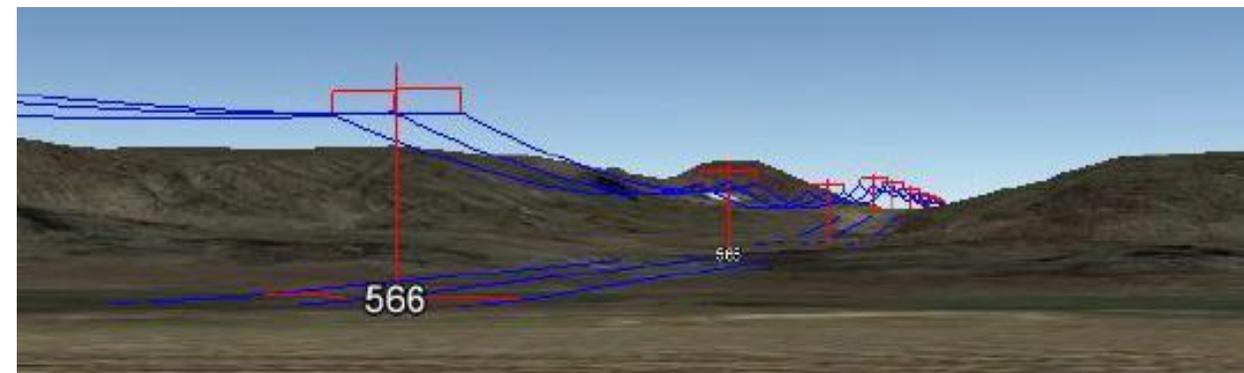
ADR VIEW IN A NUTSHELL

Input data:

- Historic weather data covering surveyed area
- Line design data and existing ratings
- Conductor features
- Span design data

Deliverables:

- ADR View report containing statistics, histograms,
- Time-stamped data in .csv format
- Presentation of results by an Ampacimon expert (face-to-face or conference call)

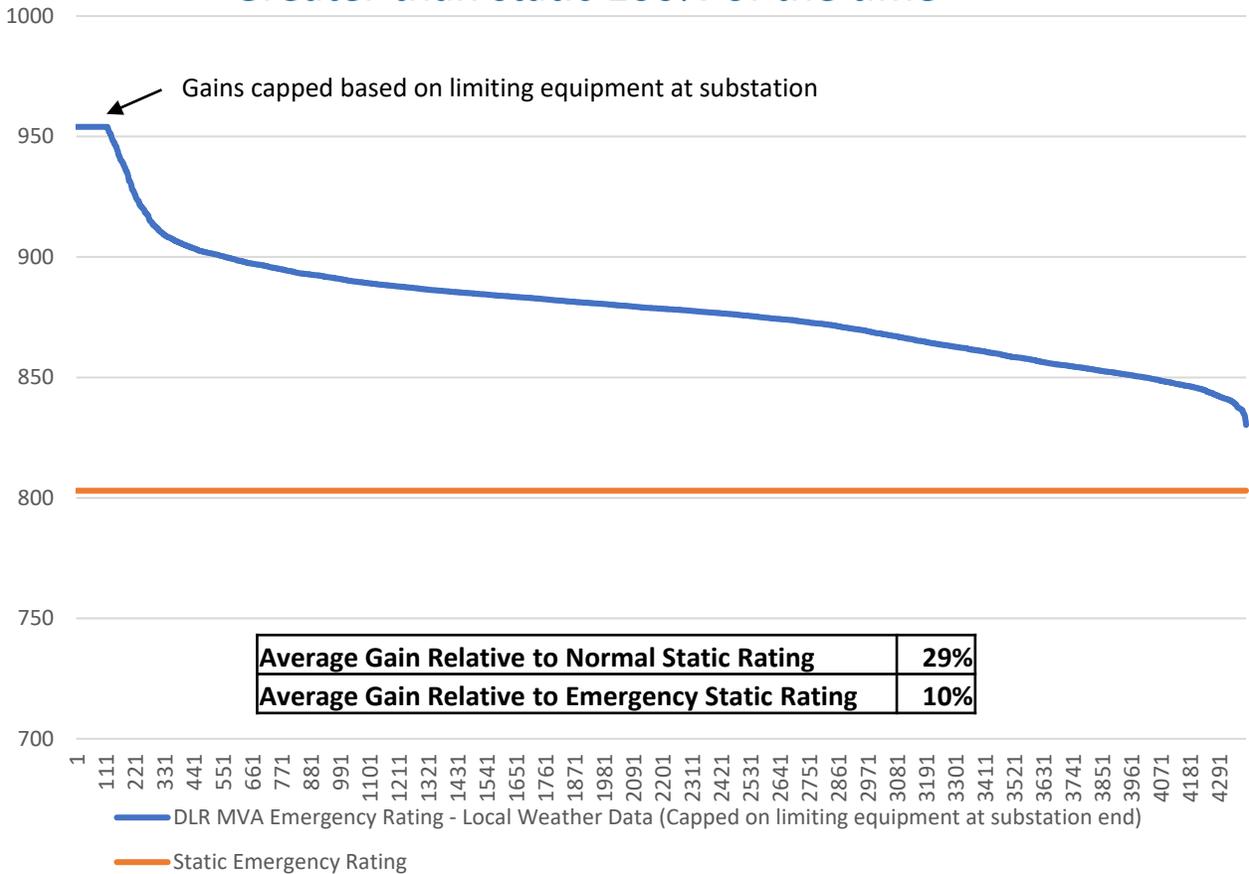


DLR Simulation Results

Steady-state DLR at emergency rating temperature

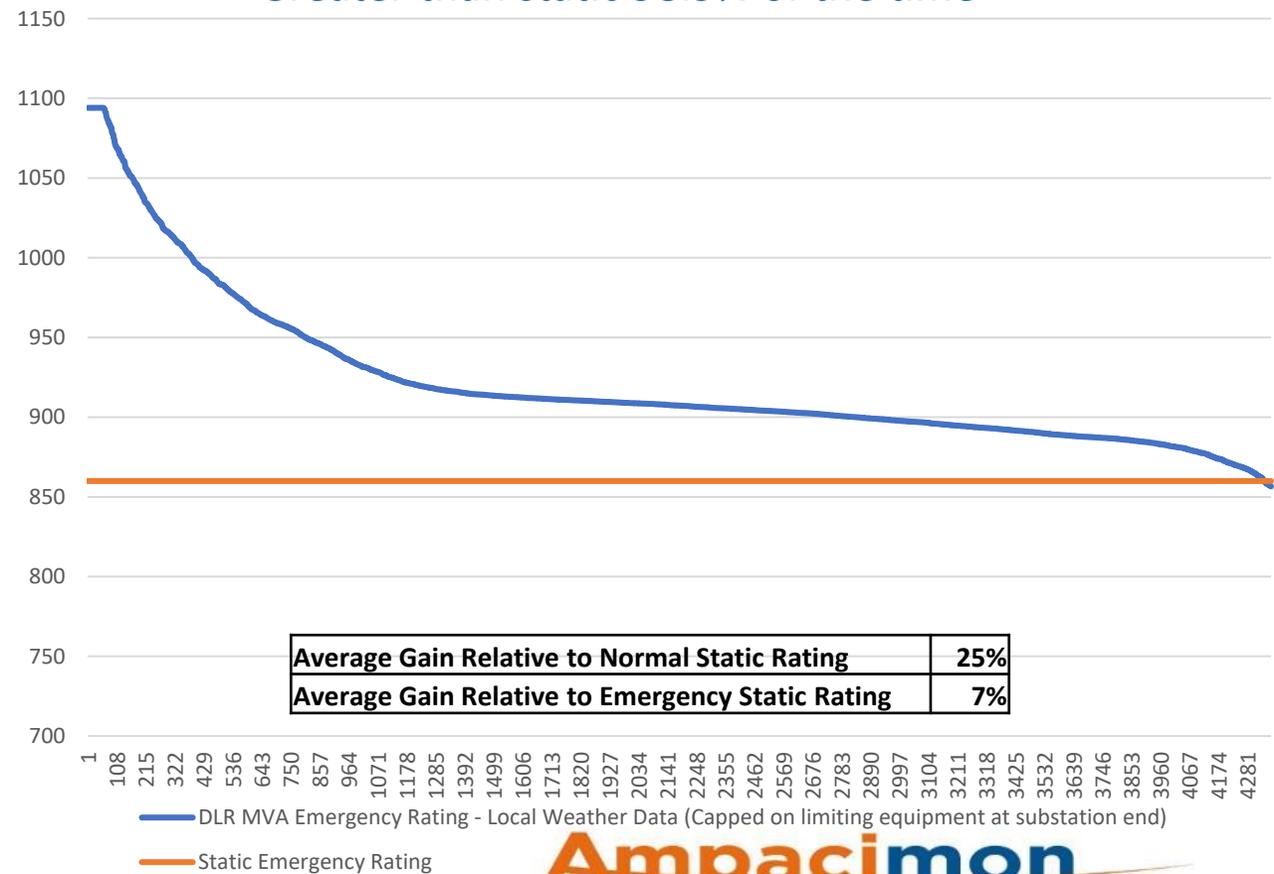
SUSQ-HARW Summer Emergency Rating (MVA)
(April-September)

Greater than static 100% of the time



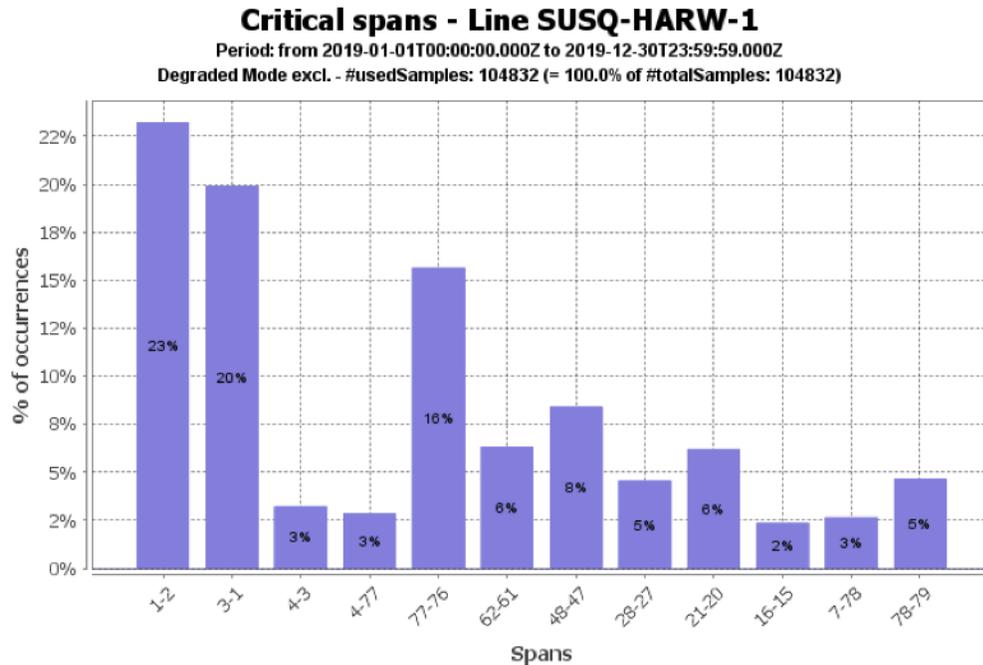
SUSQ-HARW Winter Emergency Rating (MVA)
(October-March)

Greater than static 98.9% of the time



Target Span Identification

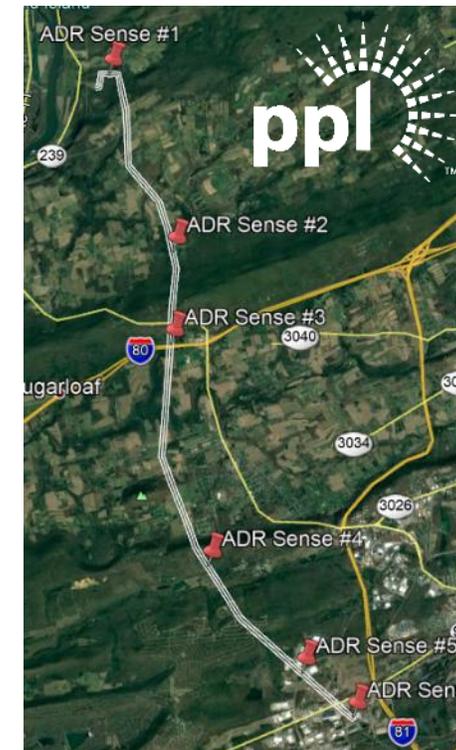
1 Critical Span Distribution From DLR Simulation



2 Required Span Selection Rules

- Orientation between spans changes more than 15°
- Distance is greater than 10 km
- Conductor or number of sub-conductor change
- Span safety concerns
- Utility span data identifies high risk span(s)

3 Final Span Selection



Sensor Deployment Complete

Susquehanna – Harwood | 2 Circuits | 12 Sensors

- One phase per identified span
- Live Line Installation Via Helicopter
- Installed December 2020
- Mounting procedure is 15 minutes per sensor
- Sensor mounted 5 – 10% of the total span length from either tower



Upcoming Work

- Definition of formal ratings procedure being developed by PPL in partnership with PJM
- Integration of ratings into PJM 1-day ahead operations and market to clear congestion violations
- Finalize IT System with NERC-CIP Compliance



Joey Alexander

Director, Business Development
Ampacimon
Joey.Alexander@Ampacimon.com

David Quier

Director, Transmission Asset Management
PPL Electric Utilities
DAQuier@pplweb.com

