

EAPA Spring 2023 Meeting  
4/25/2023

## PPL's Dynamic Line Ratings Implementation

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PPL Electric Utilities

# Background

\$23.5 Million in annual congestion costs projected in 2025

Harwood to Susquehanna #1 & #2 | 230 kV | ACSS |

Juniata to Cumberland | 230 kV | ACSR |

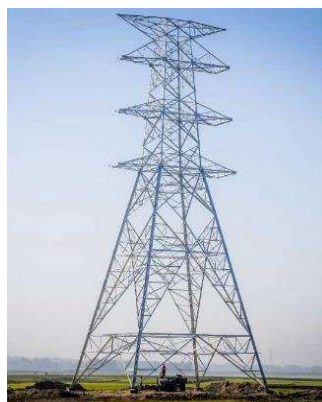
2020/21 RTEP Market Efficiency Window Eligible Energy Market Congestion Drivers* (Posted 03-05-2021)				ME Base Case (Annual Congestion \$million)		ME Base Case (Hours Binding)	
FG#	Constraint	FROM AREA	TO AREA	2025 Simulated Year	2028 Simulated Year	2025 Simulated Year	2028 Simulated Year
ME-1	Kammer 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



Rebuild



Dynamic Line Rating



Time to Implement	2 – 3 Years	3 – 5 Years	~1 Year
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?

DLR is a system of installed line sensors used to measure conductor and environmental real time data to determine a real time rating instead of assumed condition values.

## Existing Line Ratings

### Assumes:

- Wind speed
- Ambient Temp
- Solar Radiation

2 Seasons (Summer & Winter) (Planning)

Ambient Adjusted (Operations)

- Conservatively Calculates Ratings

## Dynamic Line Ratings

### Measures:

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

Provides Accurate Real Time Ratings

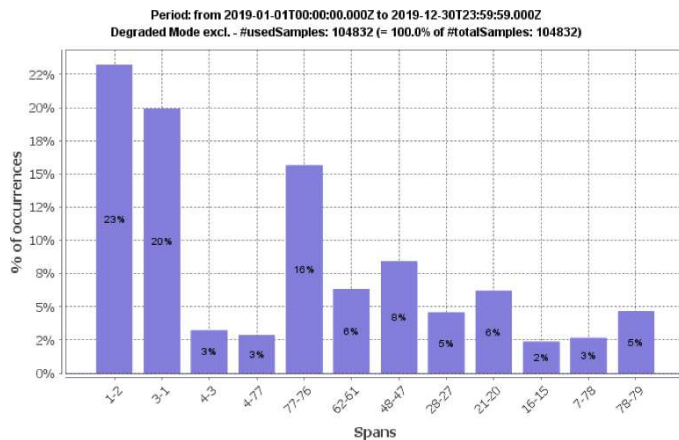
Allows for Forecasted Rating

- Measures Conductor Health



# Target Span Identification

## 1 Critical Span Distribution From DLR Simulation



## 2 Required Span Selection Rules

- Orientation between spans changes more than 15°
  - → To capture variability in wind direction
- 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



## 4 Installation

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

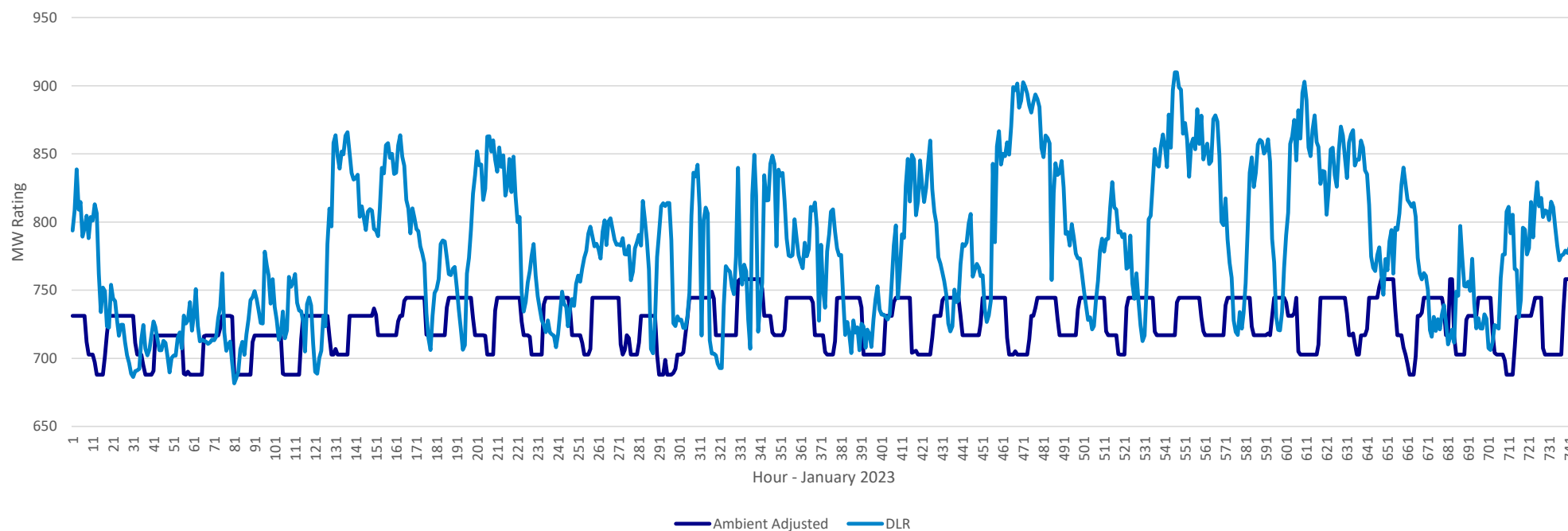


# JUNI-CUMB In-Service Results

JUNI-CUMB (ACSR) Fully in-service in October:

- ~18% Average Normal Rating Increase
- ~9% Average Emergency Rating Increase
- Congestion drop from >\$60 million to ~\$1.6 Million for winter 2021-22 to 2022-23

JUNI-CUMB Emergency Rating - January 2023

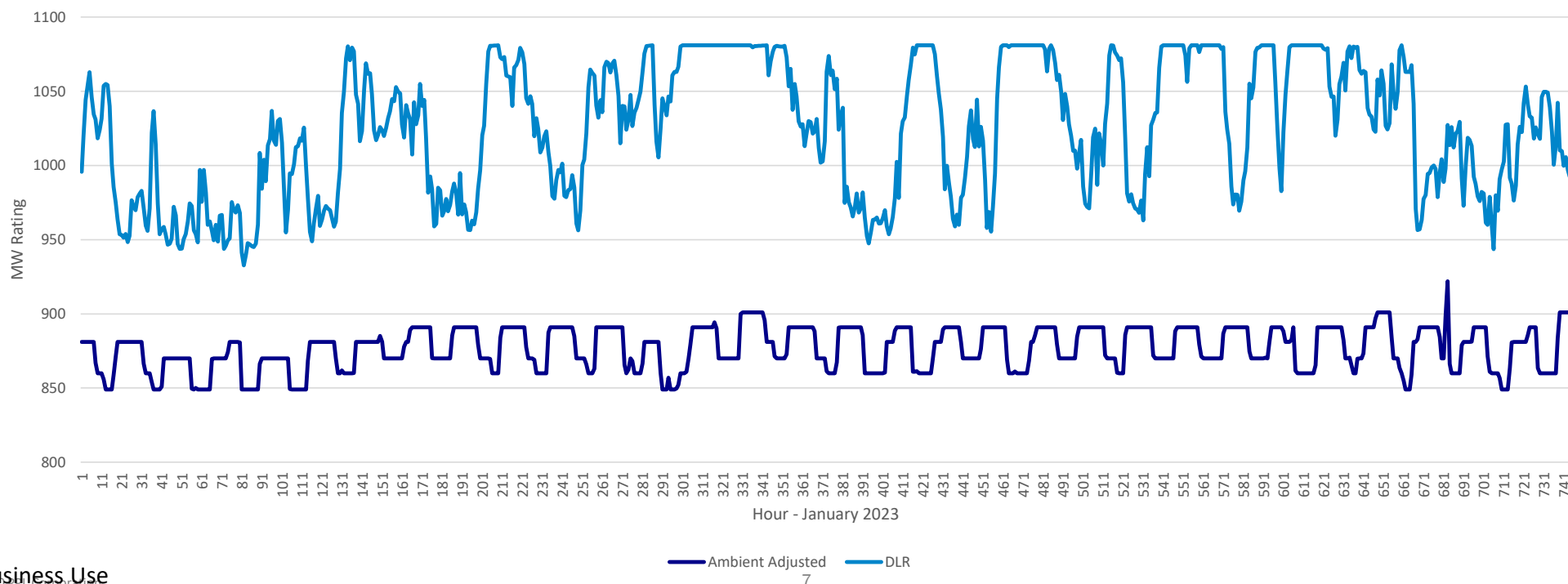


# SUSQ-HARW In-Service Results

SUSQ-HARW #1 & #2 (ACSS) Fully in-service in December:

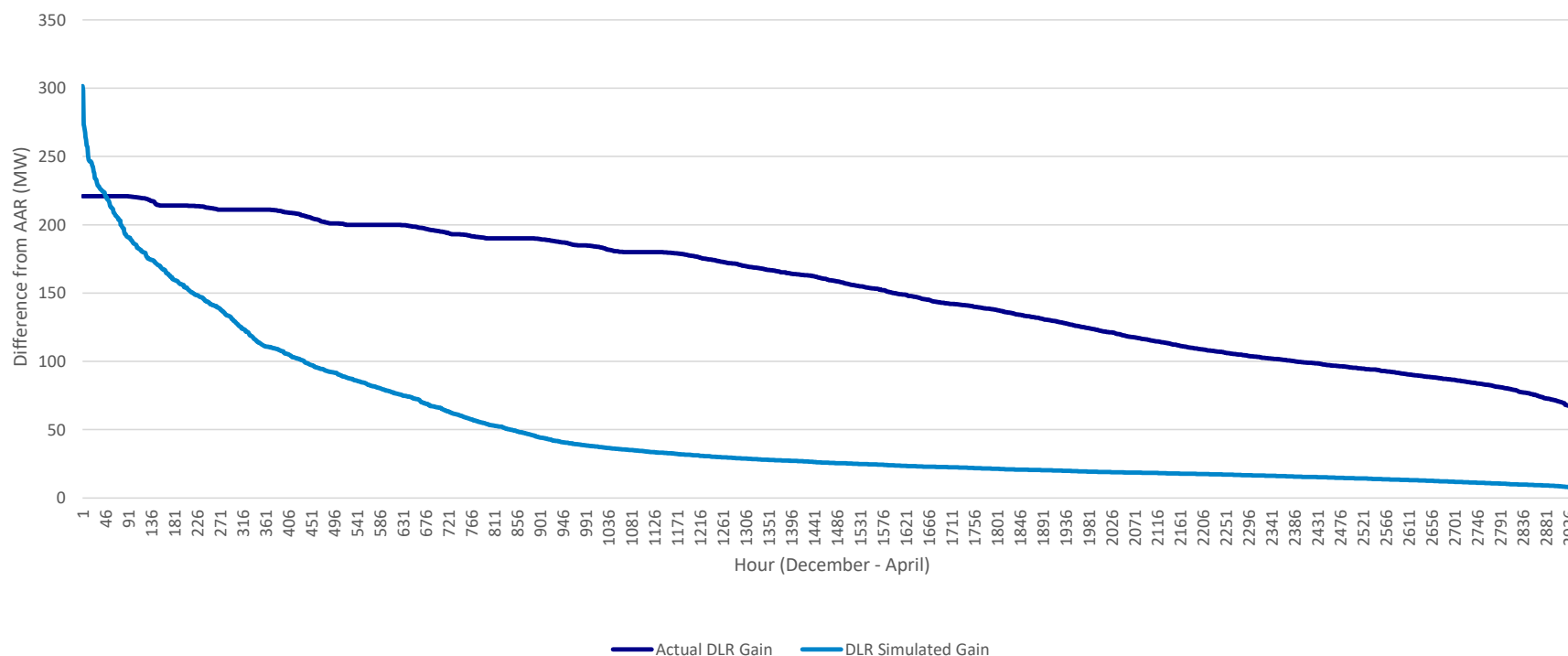
- ~19% Average Normal Rating Increase
- ~17% Average Emergency Rating Increase
- Congestion drop from ~\$2 million to ~\$0 for winter 2021-22 to 2022-23

SUSQ-HARW #1 Emergency Rating - January 2023



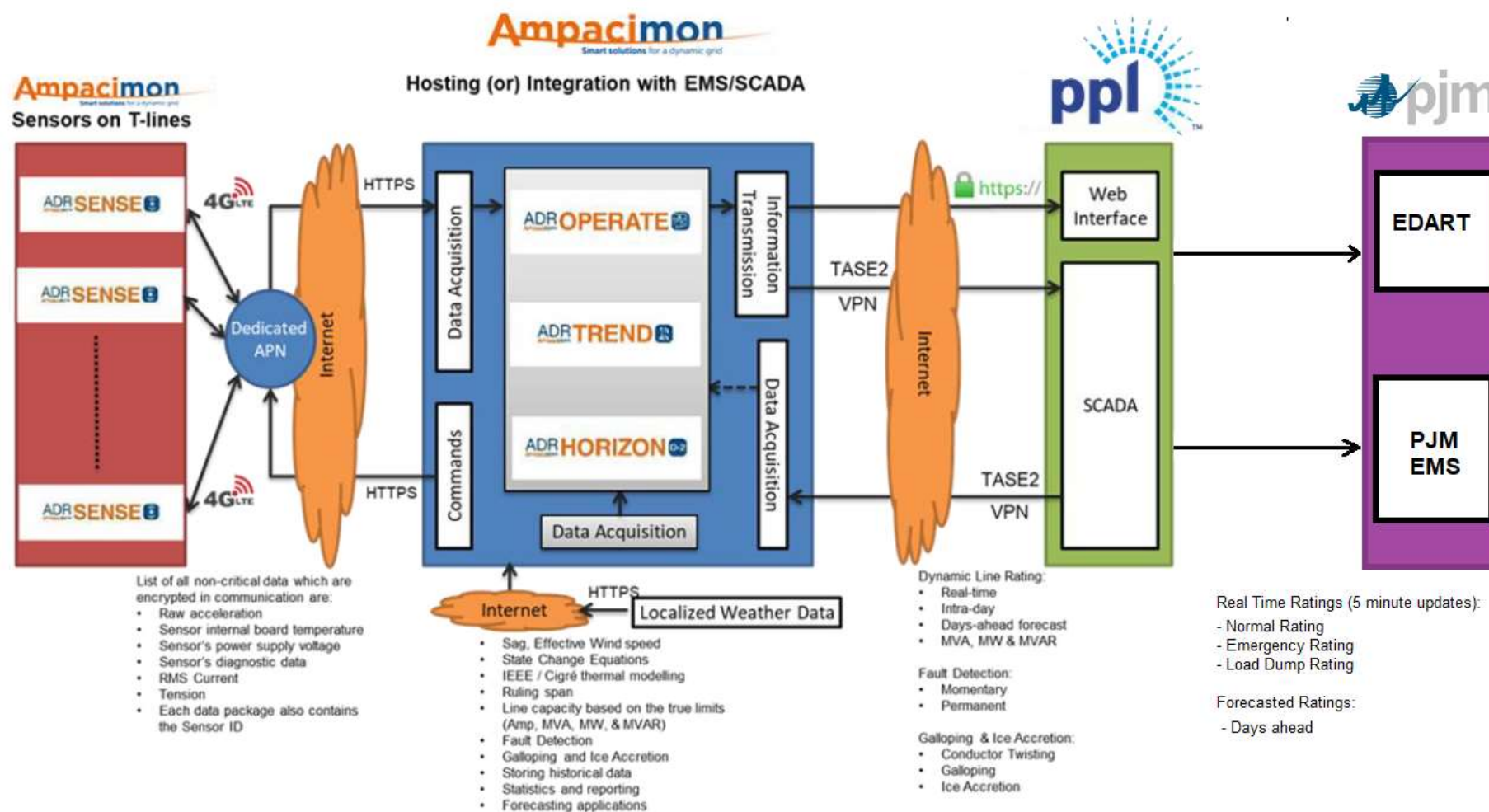
# DLR Simulation Vs Actual

## SUSQ-HARW DLR Simulation Data Vs Actual at Emergency Rating Temperature (Winter Months)

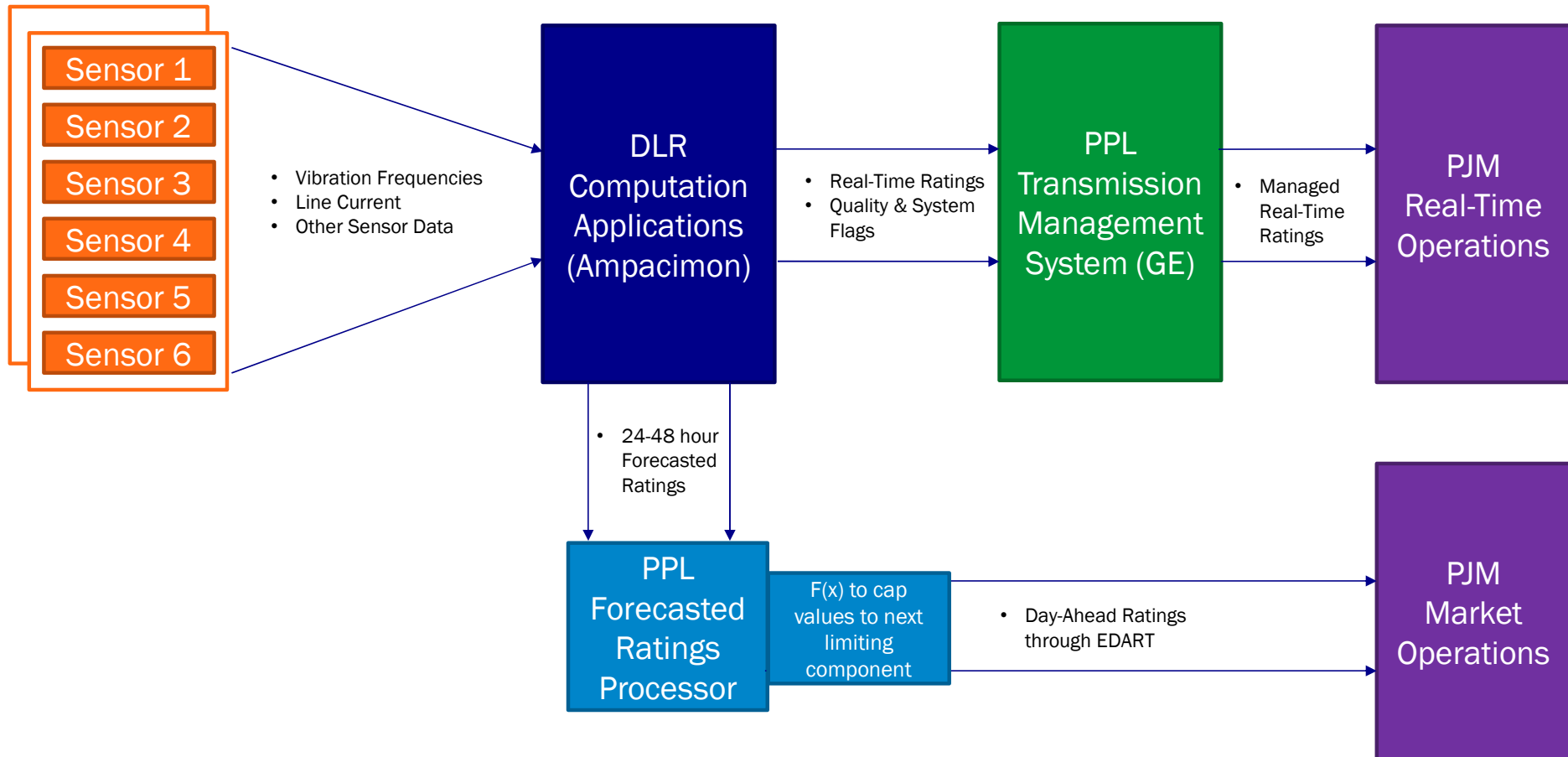




# System Overview



# Ratings Data Flow



# NERC Standards Considerations

## CIP Standards:

- CIP-002: System Categorization
- CIP-005: Electronic Security Perimeters
- CIP-006: Physical Security

PRC-023 – Relay Loadability

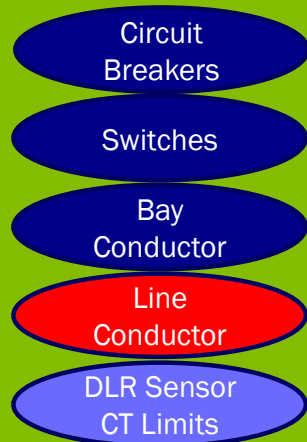
FAC-008 – Ratings Methodology



## Facility Rating Database

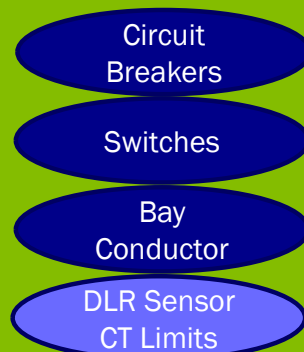
### JUNI-CUMB

Typical Line Facility  
in Rating Database



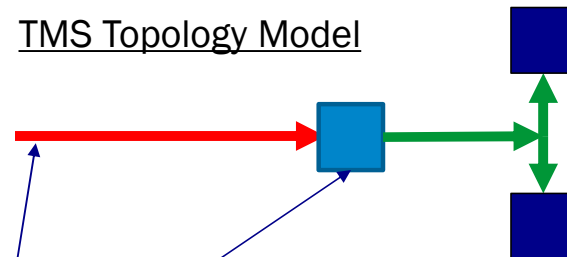
### DLR JUNI-CUMB

New DLR Line Facility  
in Rating Database



A duplicated line facility is created when DLR is applied to a line. The line conductor ratings are removed in this facility since the line conductor's rating will be dynamic.

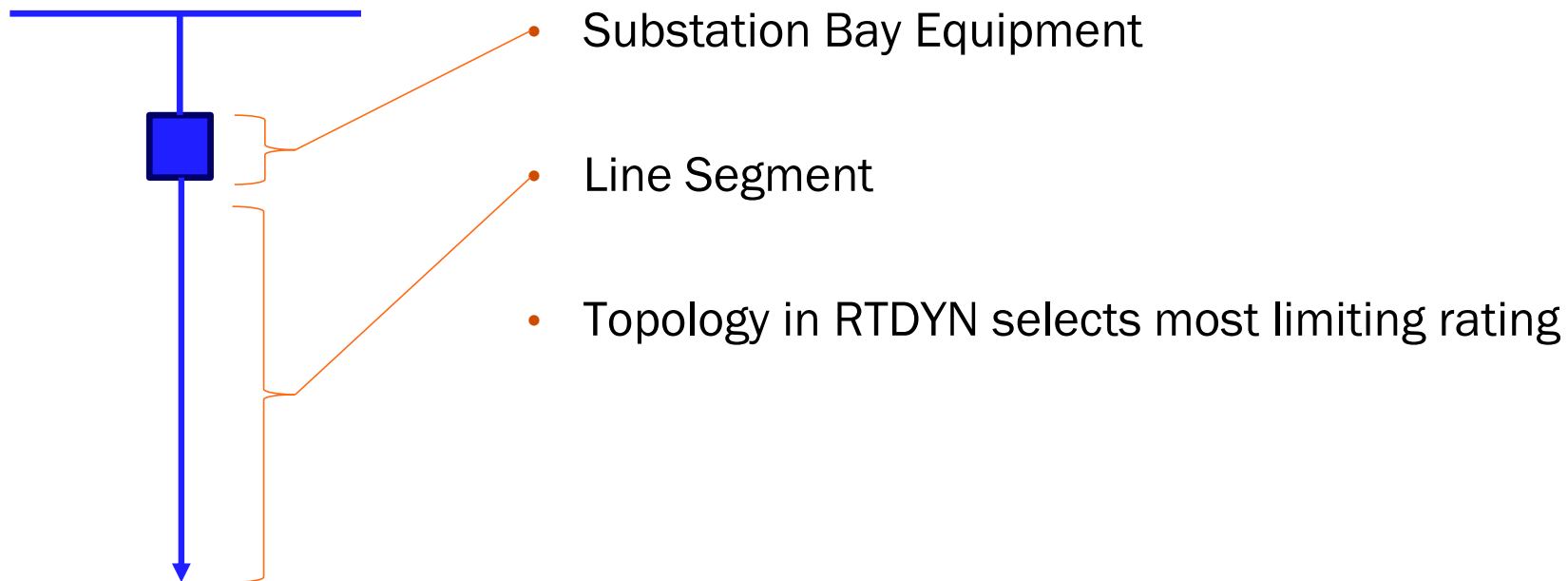
### TMS Topology Model



These are used as next most limiting component ratings to limit any ratings received from DLR.

These ratings are used as backup ratings in case DLR fails.

# TMS Topology Modeling



# DLR Telemetry Fallback Process

## Full DLR Ratings

- DLR ratings calculated to conductor sag and temperature limits from real-time line sensor data

Live Ratings From  
Ampacimon Application

Loss of 2+ line sensor  
data streams or other  
inputs

## DLR Degraded Ratings

- Ratings calculated by DLR system to conductor limits based on ambient temperature from weather and conductor measurements

Future capability

Loss of DLR  
system/telemetry  
into TMS

## GE Ambient Adjusted Ratings

- Ratings calculated by TMS, based on local ambient temperature measurements from local weather feeds to TMS

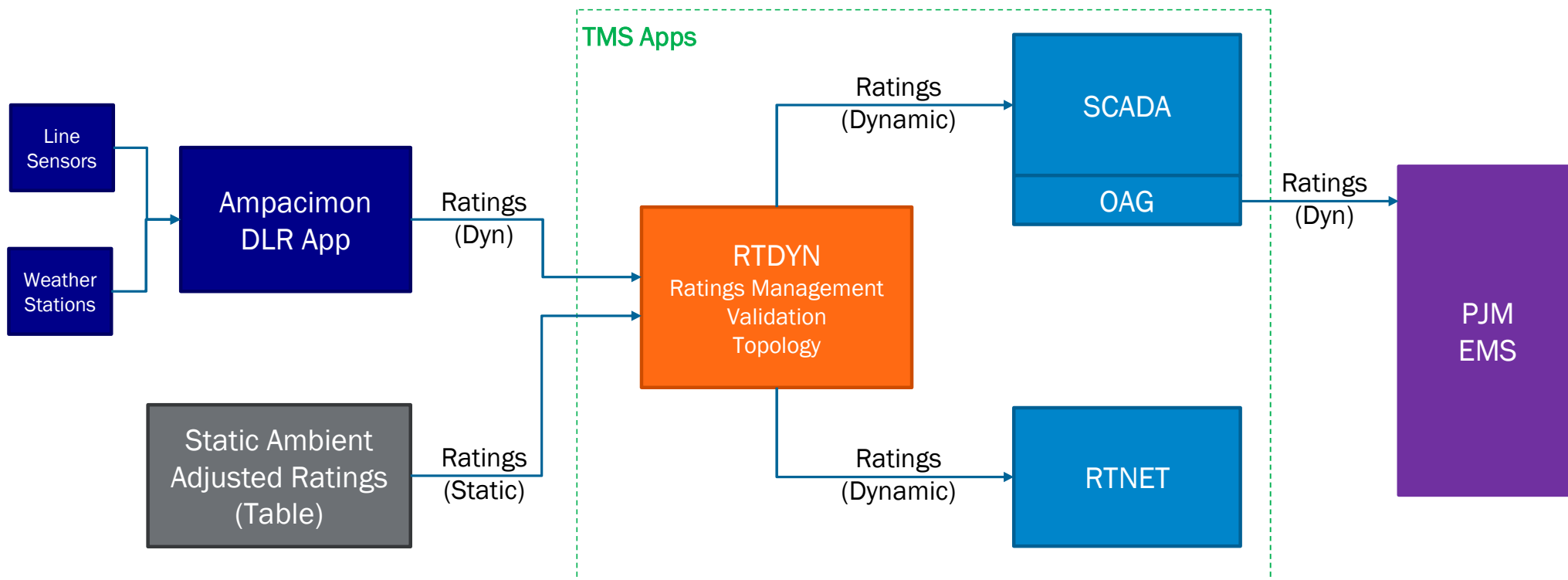
Loss of DLR  
system and  
weather input

## PPL EU Ambient Adjusted Ratings

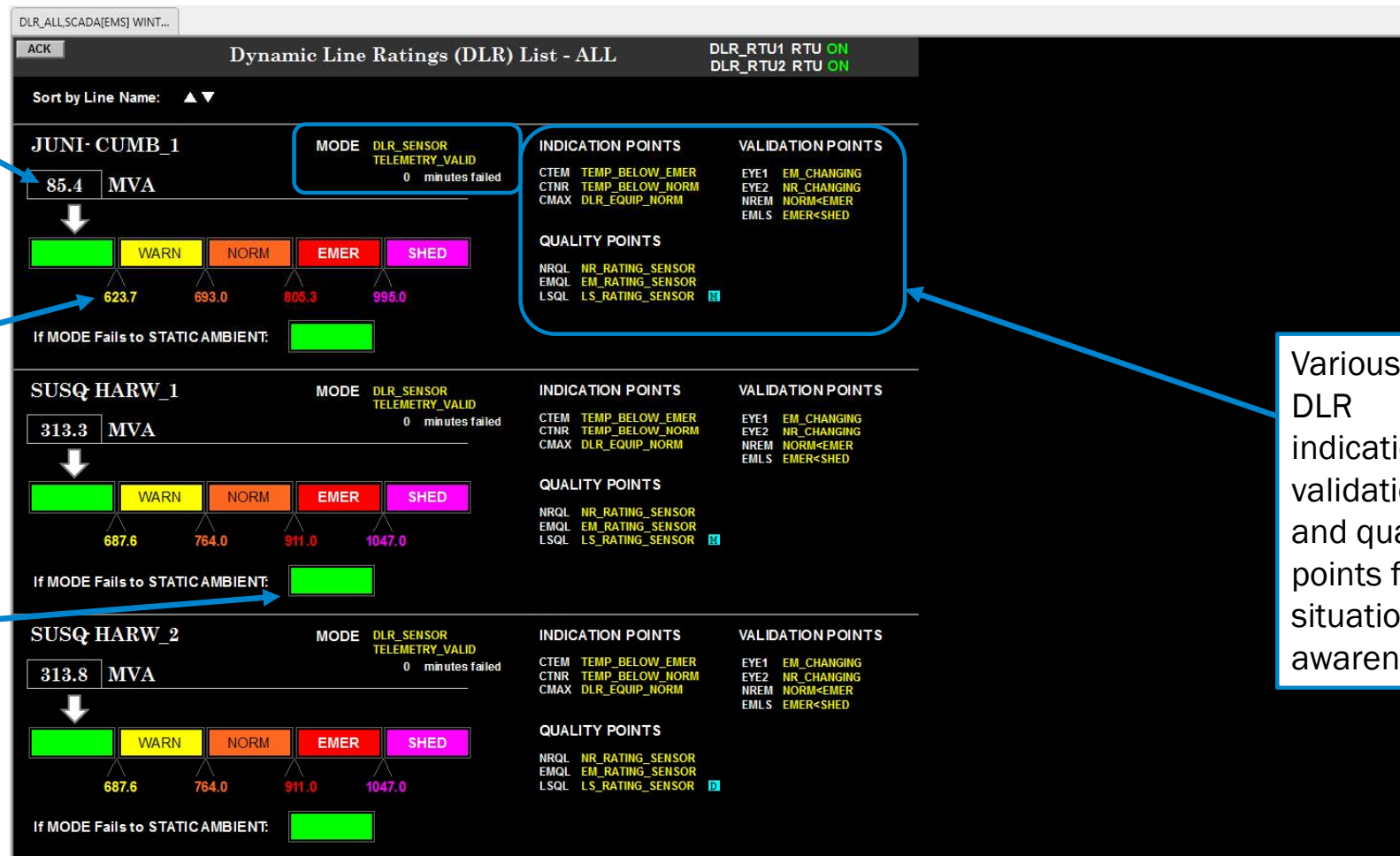
Static Ratings From  
TMS Tables



# TMS Functionality Overview



# TMS Operator Display



Current line loading

Current real-time ratings

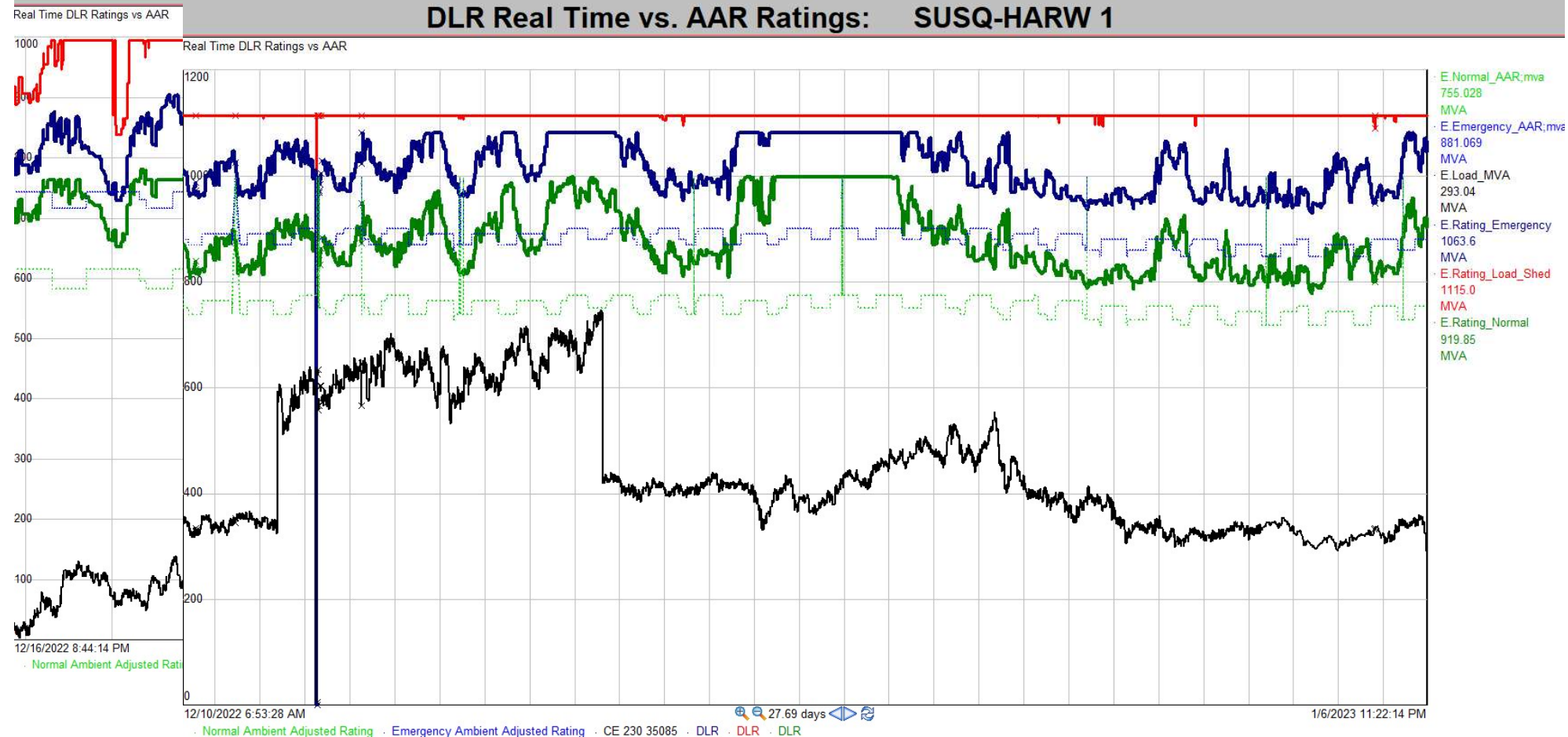
Rating Zone if DLR goes down

Various DLR indication, validation, and quality points for situational awareness

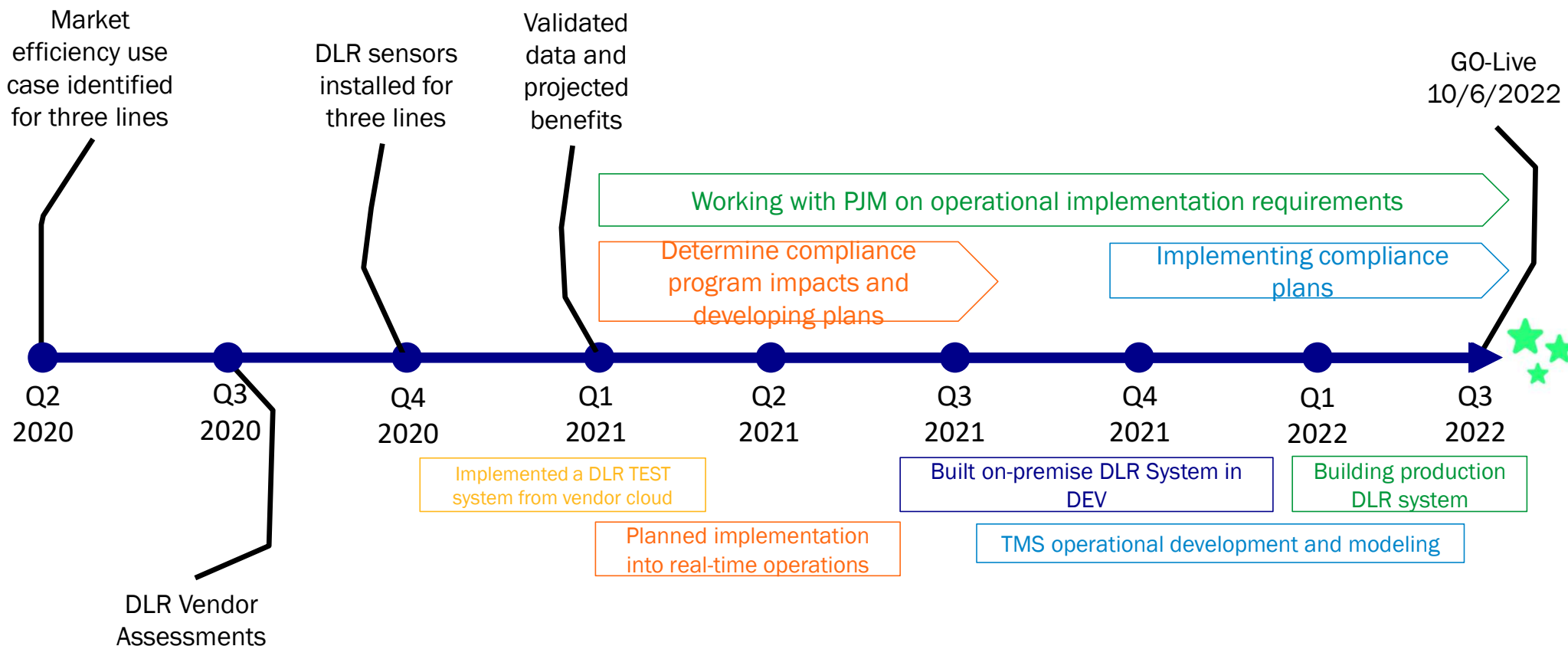
# Real Time DLR In Action

DLR Real Time vs. AAR Ratings: JUNI-CUMB

DLR Real Time vs. AAR Ratings: SUSQ-HARW 1



# Our Roadmap So Far...



## Challenges: Solved and Ongoing

- NERC standards impacts and processes
- Ratings management:
  - Failure contingency
  - Honoring next most limiting component
- Regional transmission operator and stakeholder coordination
- Best practices for ratings validation
- Ratings methodologies industry best practices:
  - Real-time
  - Long-term forecasts
- Large scale system considerations, risks and mitigations



# Questions?

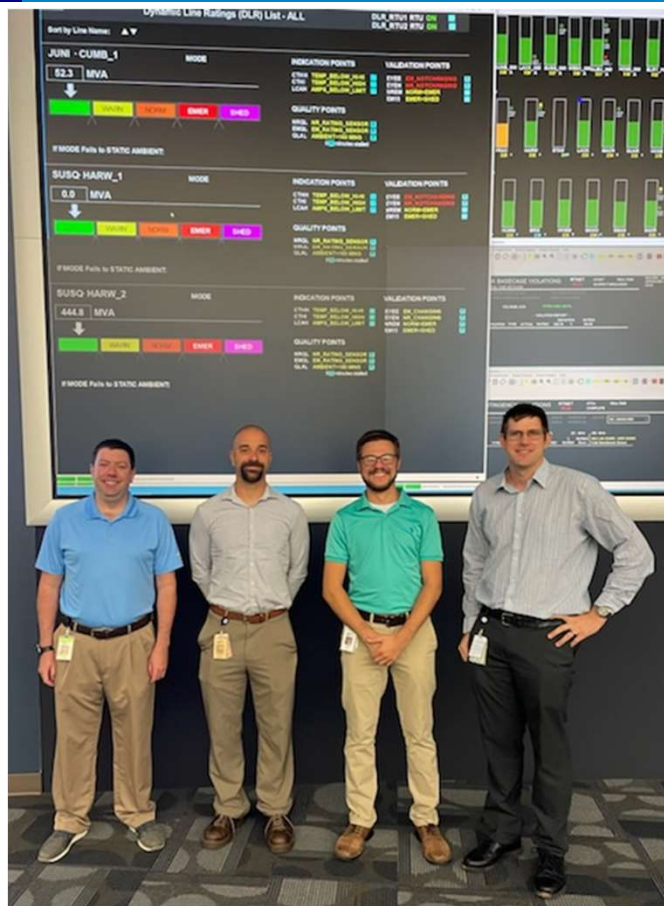


Photo of some of the DLR team members: from left, Andrew Henry, Horst Lehmann, Bill Elko, and Eric Rosenberger



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