

PJM DLR Task Force Meeting

12/12/2022

## Dynamic Line Ratings Operations Integration

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Center



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\$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

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%

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

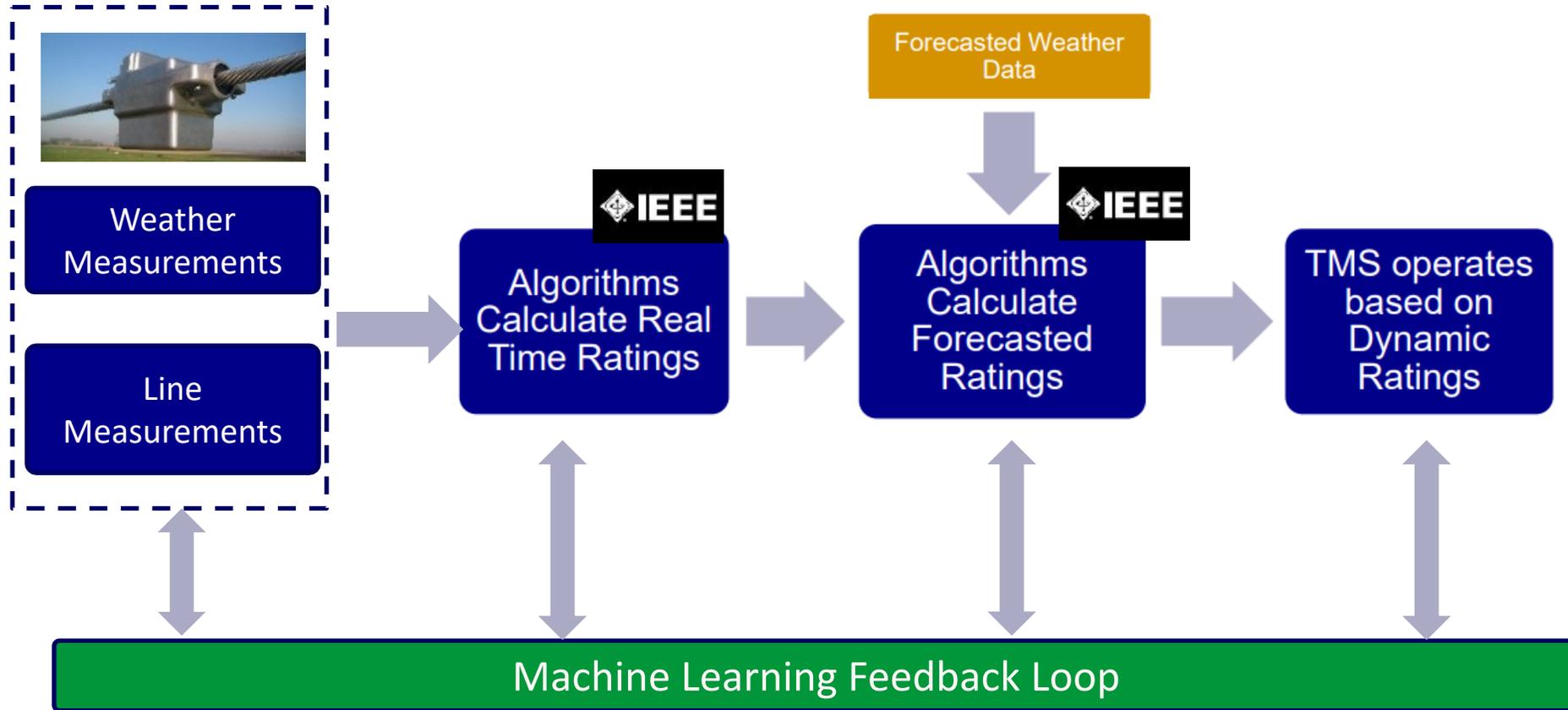
Provides Accurate Real Time Ratings

### Allows for Forecasted Rating

- Measures Conductor Health

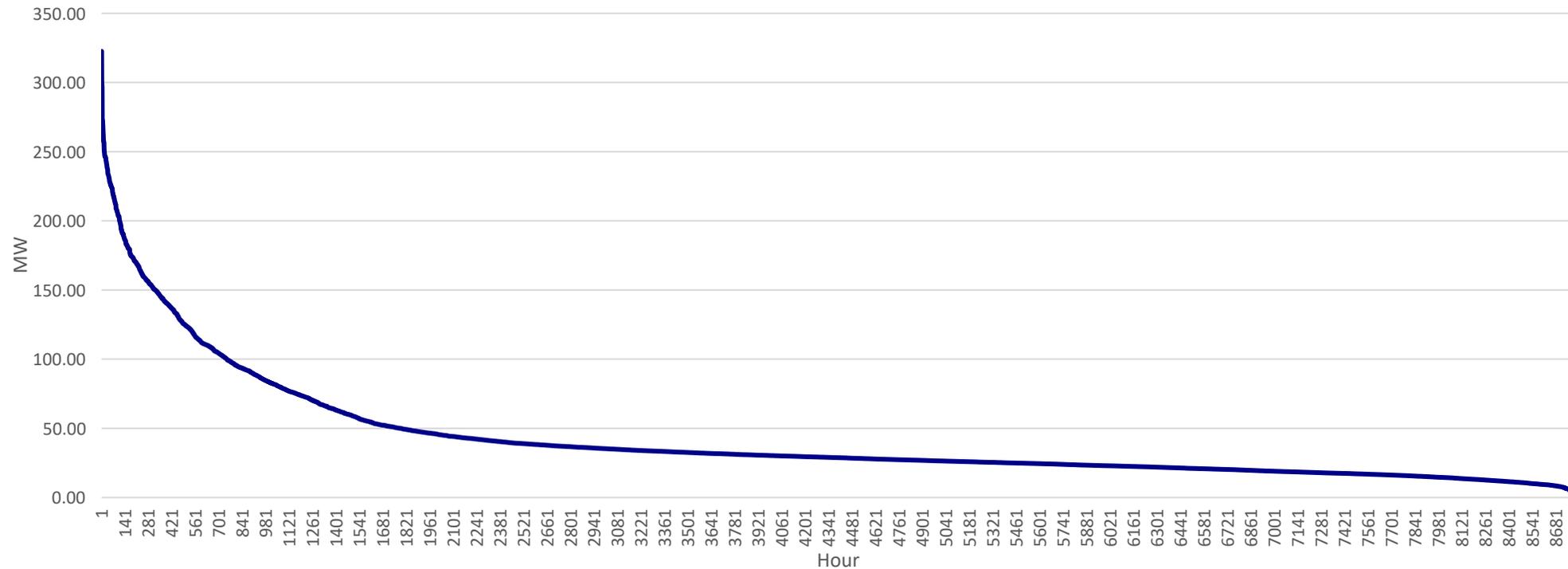
Expected average normal ratings gain of almost 30%

# Dynamic Line Ratings Process



## Steady-State DLR at Emergency Rating Temperature

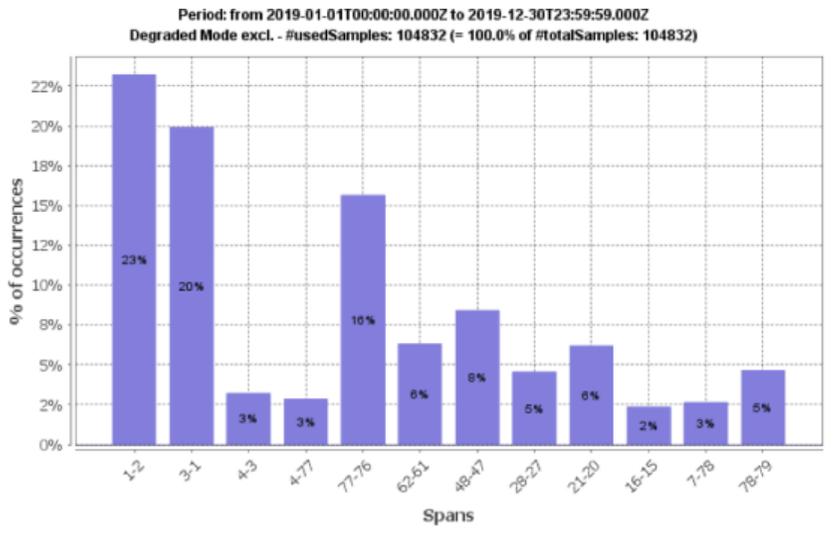
Projected rating increase on pilot 230kV line  
(DLR minus AAR)



5% average gain relative to emergency ambient adjusted rating

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



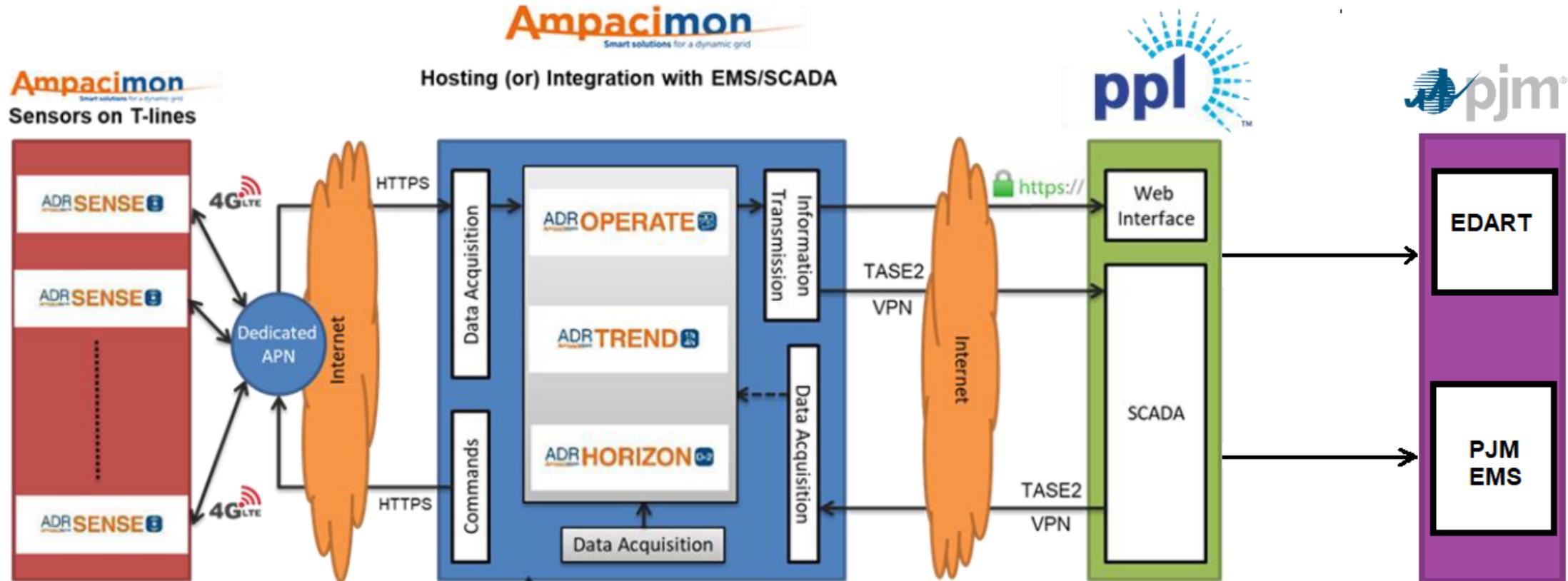
4

## 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



# System Overview



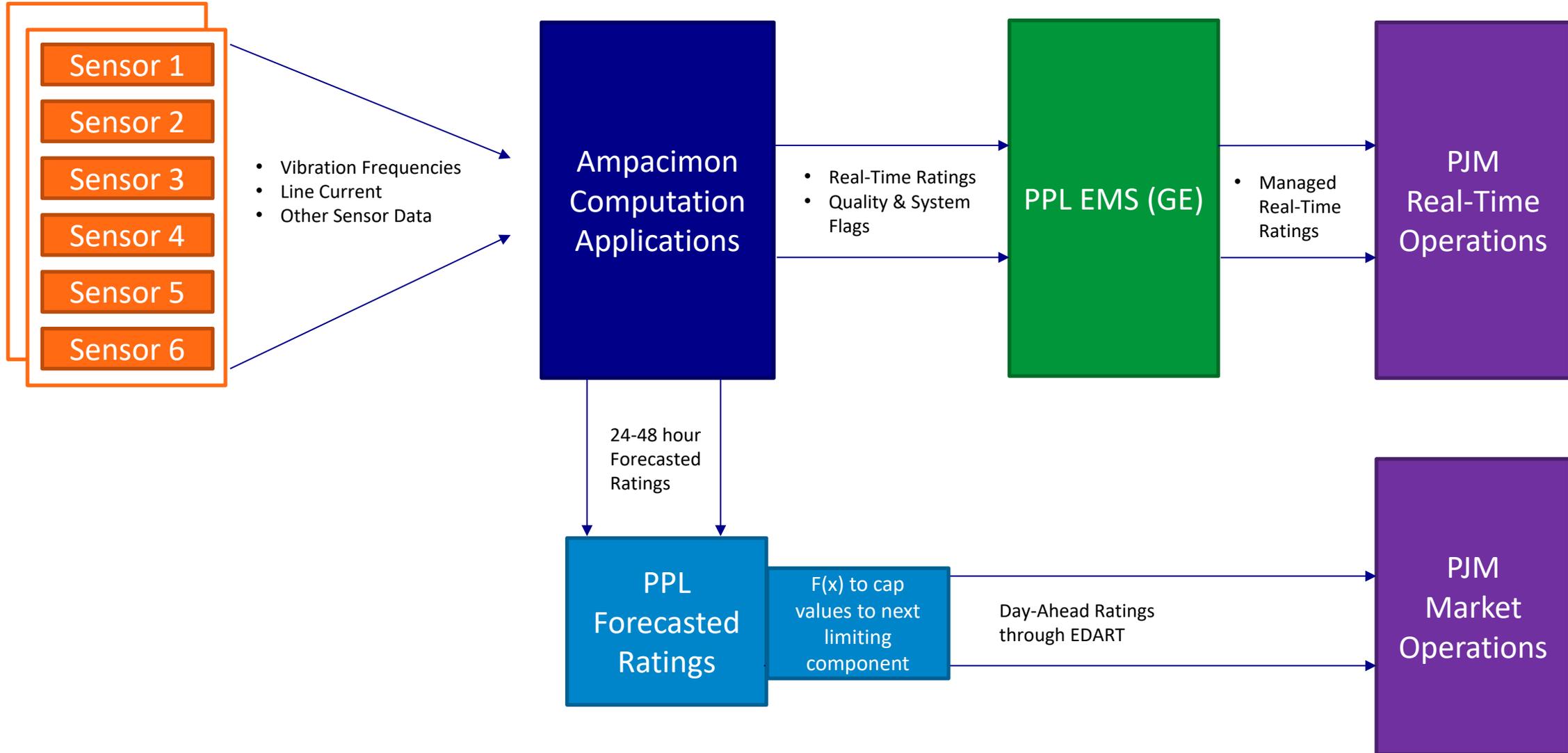
- List of all non-critical data which are encrypted in communication are:
- Raw acceleration
  - Sensor internal board temperature
  - Sensor's power supply voltage
  - Sensor's diagnostic data
  - RMS Current
  - Tension
  - Each data package also contains the Sensor ID

- Sag, Effective Wind speed
- State Change Equations
- IEEE / Cigré thermal modelling
- Ruling span
- Line capacity based on the true limits (Amp, MVA, MW, & MVAR)
- Fault Detection
- Galloping and Ice Accretion
- Storing historical data
- Statistics and reporting
- Forecasting applications

- Dynamic Line Rating:
- Real-time
  - Intra-day
  - Days-ahead forecast
  - MVA, MW & MVAR
- Fault Detection:
- Momentary
  - Permanent
- Galloping & Ice Accretion:
- Conductor Twisting
  - Galloping
  - Ice Accretion

- Real Time Ratings (5 minute updates):
- Normal Rating
  - Emergency Rating
  - Load Dump Rating
- Forecasted Ratings:
- Days ahead

# Ratings Data Flow

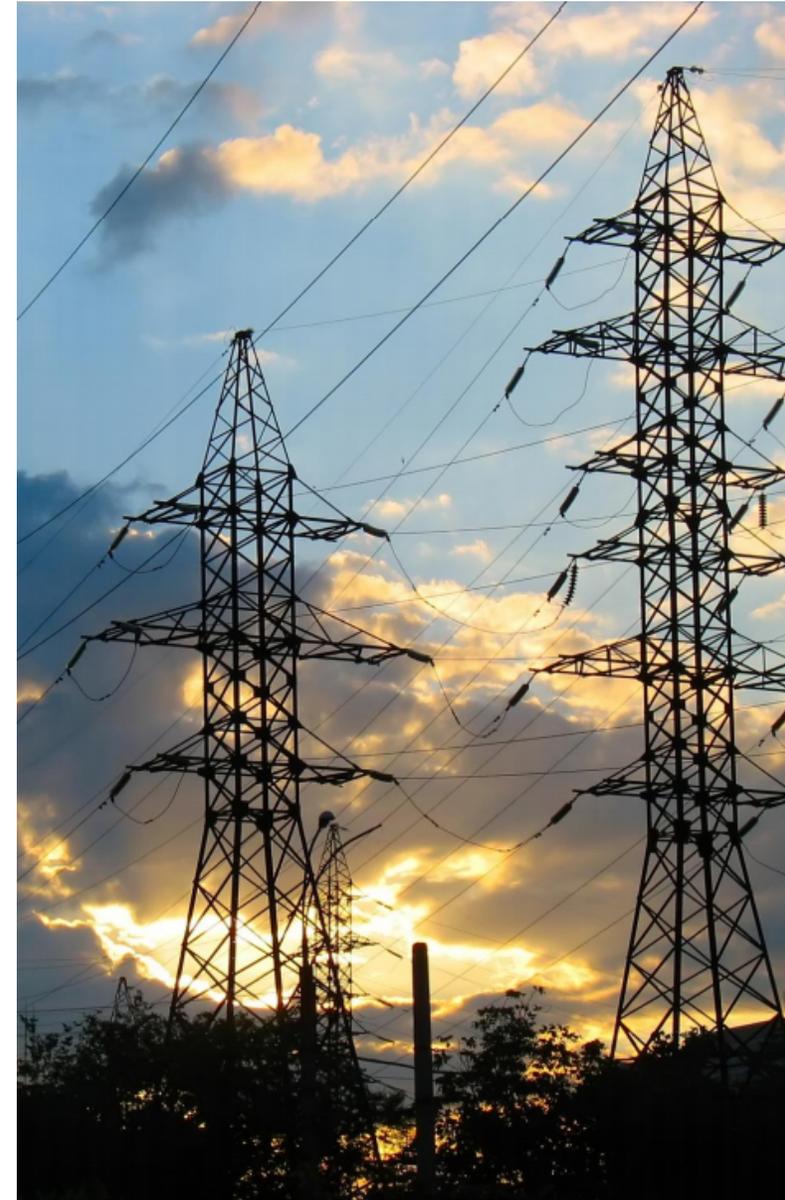


## CIP Standards:

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

PRC-023 – Relay Loadability

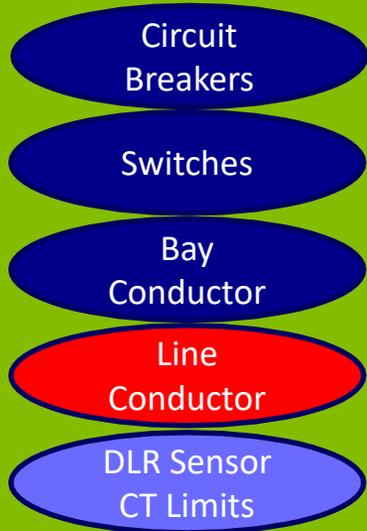
FAC-008 – Ratings Methodology



## Facility Rating Database

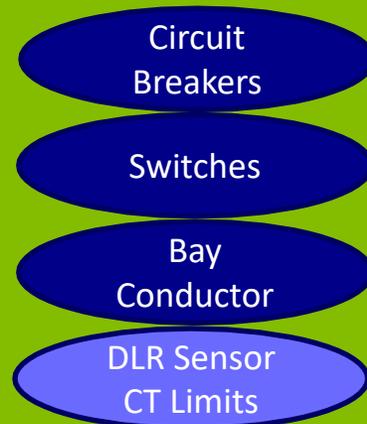
### JUNI-CUMB

Typical Line Facility  
in Rating Database



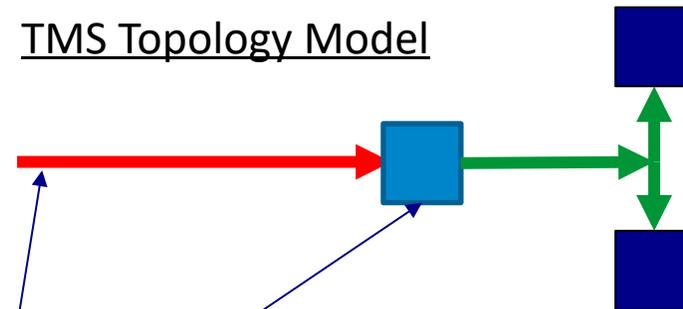
### DLR JUNI-CUMB

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.

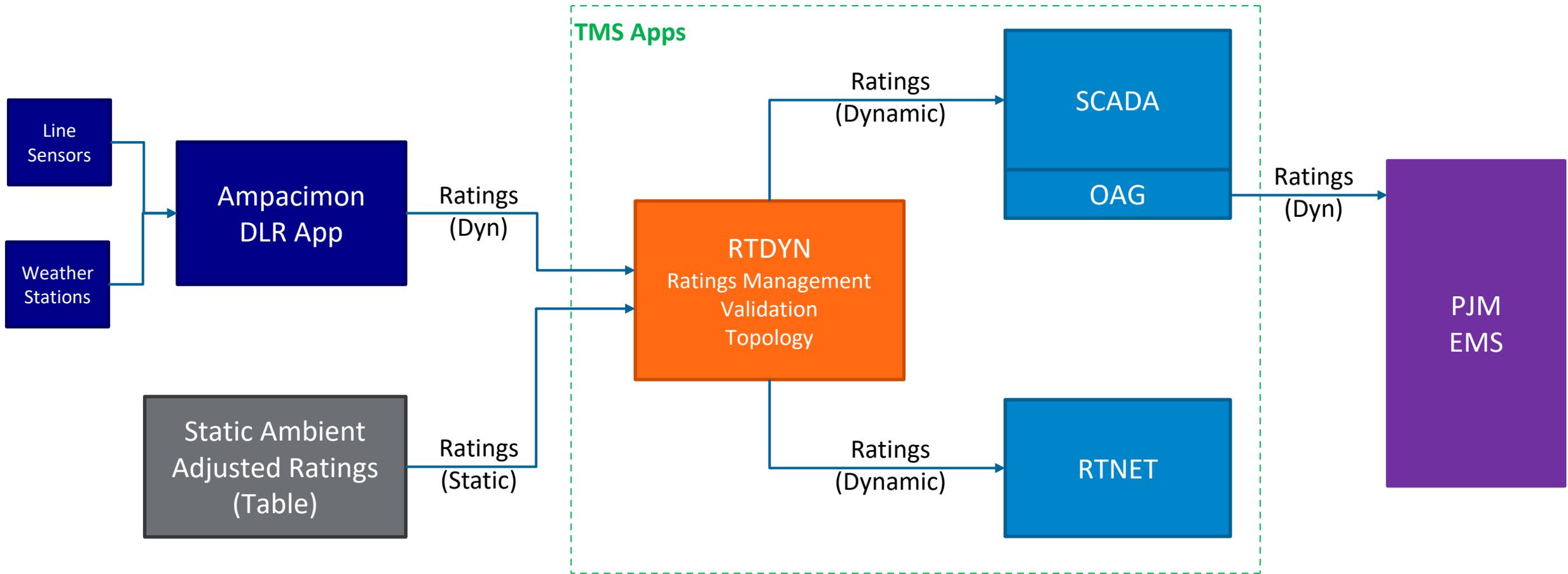
### TMS Topology Model

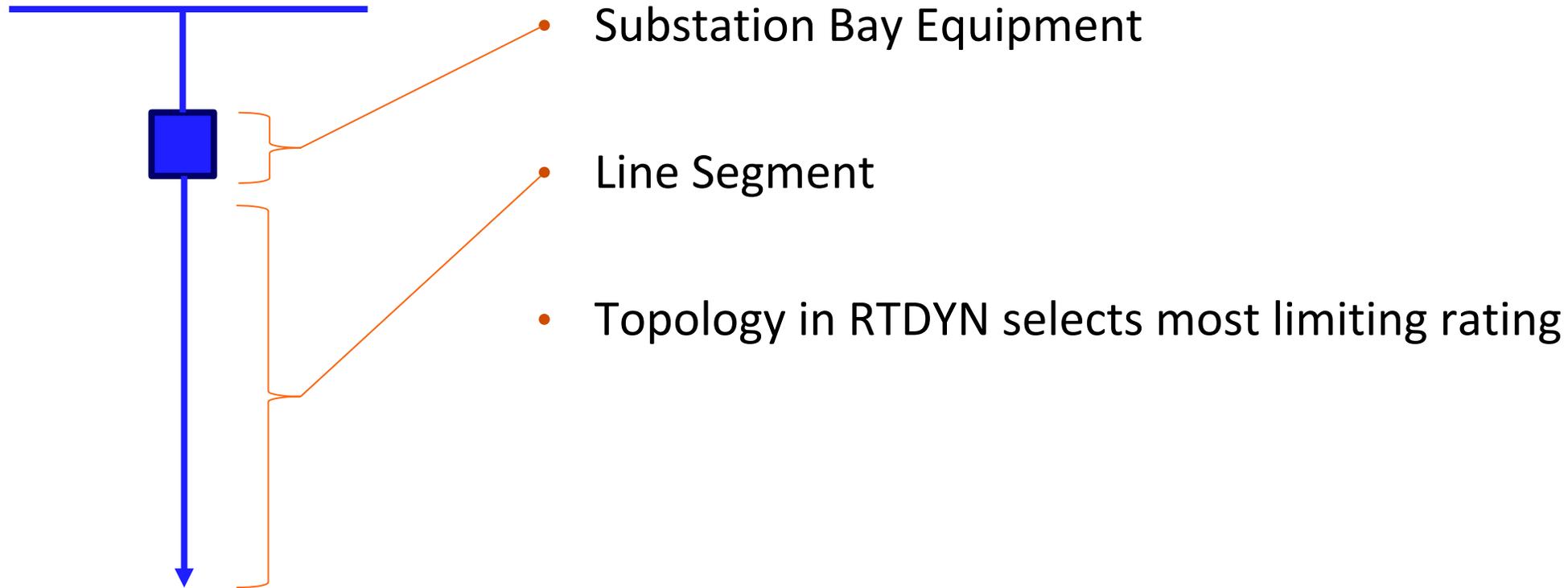


These are used as next most limiting component ratings to limit any ratings received from DLR.

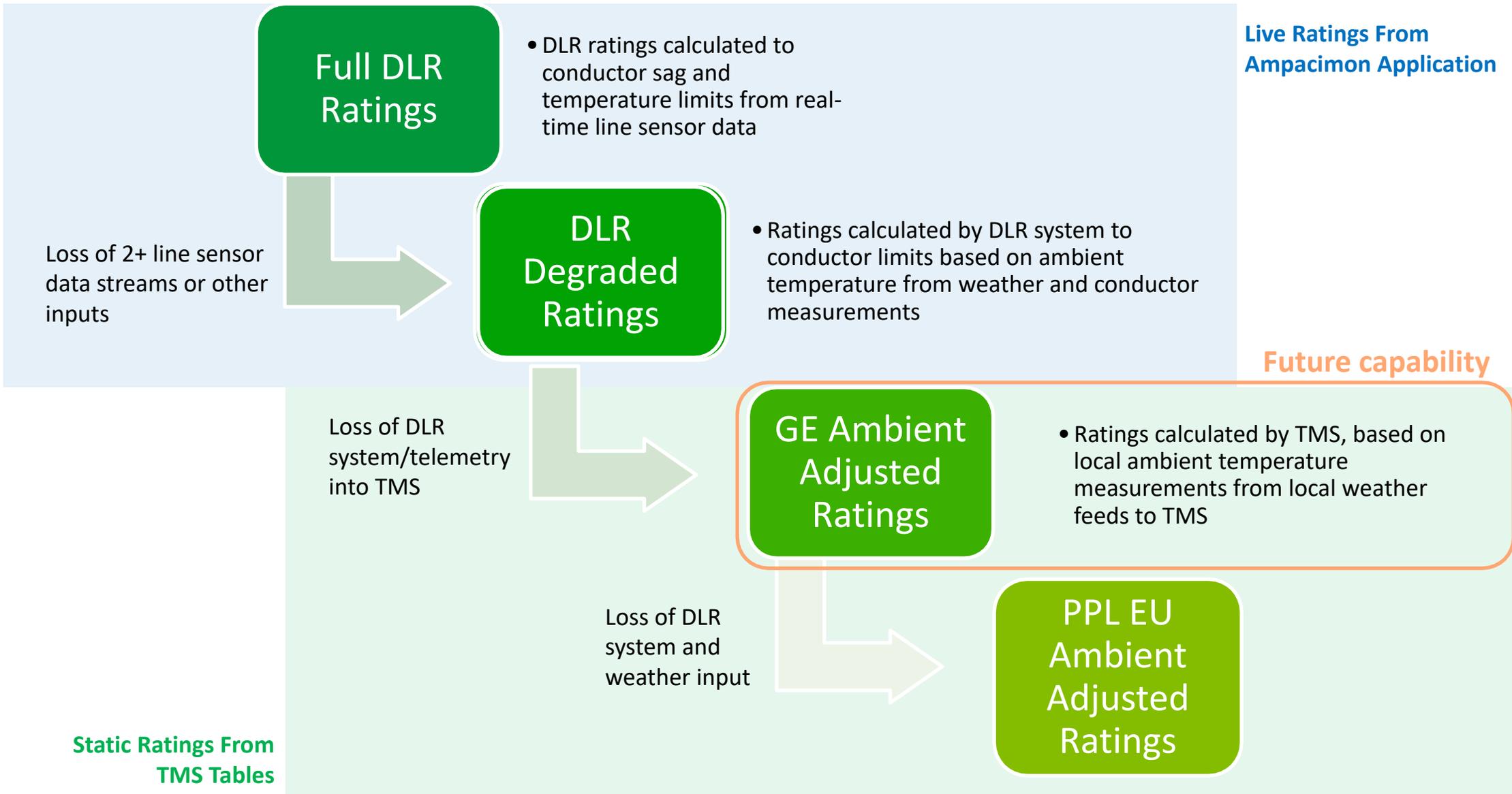
These ratings are used as backup ratings in case DLR fails.

# TMS Functionality Overview





# DLR Telemetry Fallback Process



# TMS Operator Display



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Current line loading

Current real-time ratings

Rating Zone if DLR goes down

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

DLR\_ALL,SCADA[EMS] WINT...

ACK Dynamic Line Ratings (DLR) List - ALL DLR\_RTU1 RTU ON DLR\_RTU2 RTU ON

Sort by Line Name: ▲▼

**JUNI- CUMB\_1** MODE DLR\_SENSOR TELEMETRY\_VALID 0 minutes failed

85.4 MVA

INDICATION POINTS: CTEM TEMP\_BELOW\_EMER, CTNR TEMP\_BELOW\_NORM, CMAX DLR\_EQUIP\_NORM

VALIDATION POINTS: EYE1 EM\_CHANGING, EYE2 NR\_CHANGING, NREM NORM<EMER, EMLS EMER<SHED

QUALITY POINTS: NRQL NR\_RATING\_SENSOR, EMQL EM\_RATING\_SENSOR, LSQL LS\_RATING\_SENSOR

623.7 693.0 805.3 995.0

If MODE Fails to STATIC AMBIENT: [Green]

**SUSQ HARW\_1** MODE DLR\_SENSOR TELEMETRY\_VALID 0 minutes failed

313.3 MVA

INDICATION POINTS: CTEM TEMP\_BELOW\_EMER, CTNR TEMP\_BELOW\_NORM, CMAX DLR\_EQUIP\_NORM

VALIDATION POINTS: EYE1 EM\_CHANGING, EYE2 NR\_CHANGING, NREM NORM<EMER, EMLS EMER<SHED

QUALITY POINTS: NRQL NR\_RATING\_SENSOR, EMQL EM\_RATING\_SENSOR, LSQL LS\_RATING\_SENSOR

687.6 764.0 911.0 1047.0

If MODE Fails to STATIC AMBIENT: [Green]

**SUSQ HARW\_2** MODE DLR\_SENSOR TELEMETRY\_VALID 0 minutes failed

313.8 MVA

INDICATION POINTS: CTEM TEMP\_BELOW\_EMER, CTNR TEMP\_BELOW\_NORM, CMAX DLR\_EQUIP\_NORM

VALIDATION POINTS: EYE1 EM\_CHANGING, EYE2 NR\_CHANGING, NREM NORM<EMER, EMLS EMER<SHED

QUALITY POINTS: NRQL NR\_RATING\_SENSOR, EMQL EM\_RATING\_SENSOR, LSQL LS\_RATING\_SENSOR

687.6 764.0 911.0 1047.0

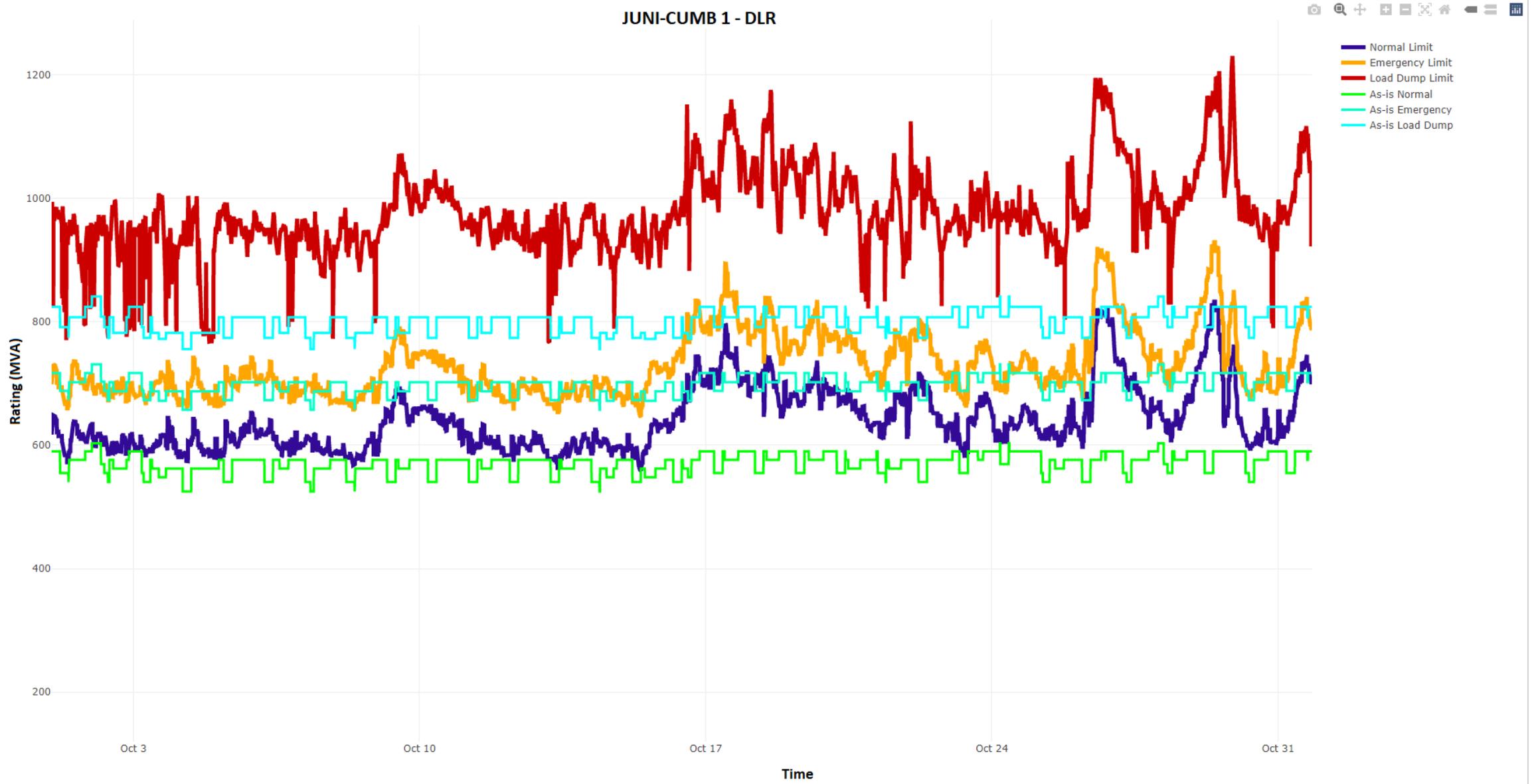
If MODE Fails to STATIC AMBIENT: [Green]

# Sample DLR Data

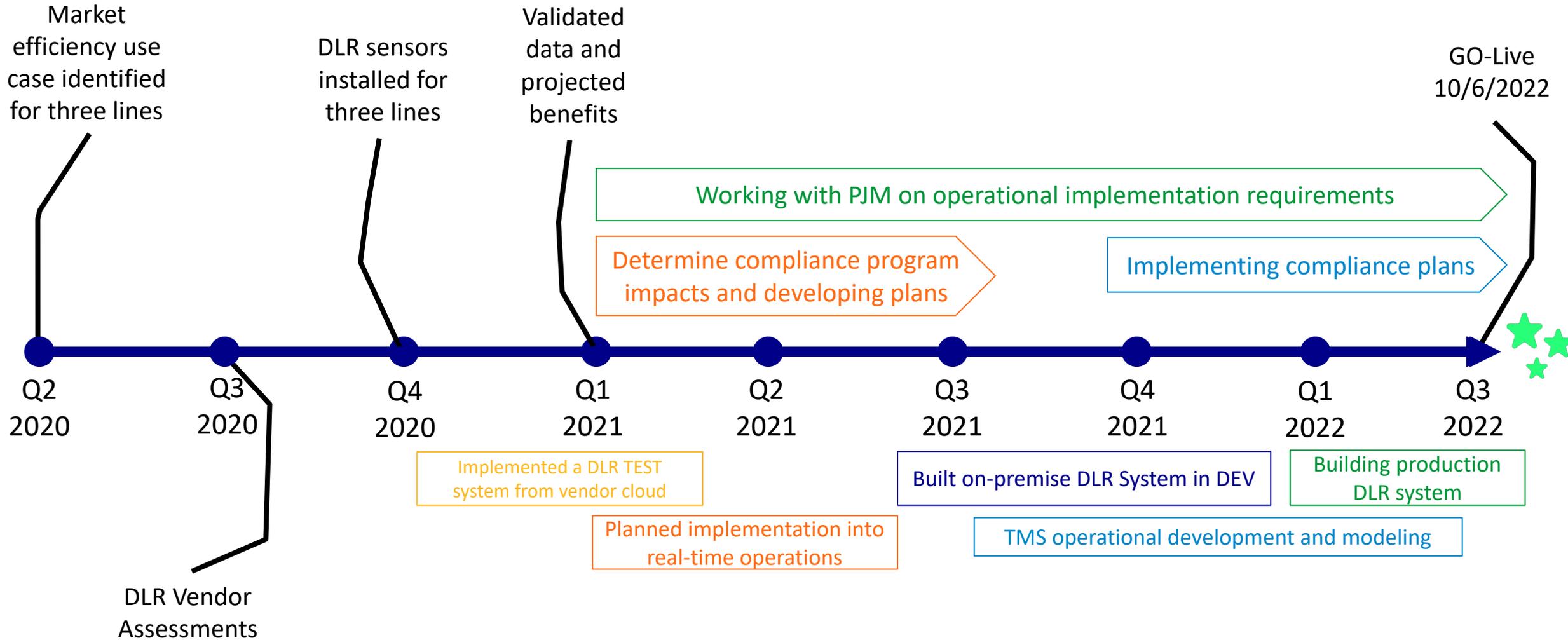


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### JUNI-CUMB 1 - DLR



# Our Roadmap So Far...



- 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 integration team members: from left, Andrew Henry, Horst Lehman, Bill Elko, and Eric Rosenberger*

