



PPL Electric Utilities

We Deliver.

Dynamic Line Ratings Strategy

Current PPL Transmission Grid



Star 11062019 13:00, End 12260219 13:00 19-00042 Est# 788799
 Job Sheet 11000019 09:00 REV # 1 Work Order 5622820

To Note: 1388KV Transformer No. 4, 88KV Operating Bus sections No. 2 and 3 and the 88KV Inspection Bus at Westerville substation, including the Westerville-Westerville No. 2 88KV line, Westerville sub to 88KV lines 888744020, and the Westerville-South Foperville No. 1 88KV line, Westerville sub to 88KV lines 887244025, and the Westerville-Springdale No. 1 88KV line, Westerville sub to the Westerville No. 1 88KV line 8811400 811324430; out of service to test connections, and place in service 88KV Bus Tie relay schemes related to 88KV Bus Section 3 in the new Control House. Replace the Bus Sect. 2-3 88KV GOO, replace the Operating Bus Line, Inspect the Bus 88KV Disconnect, Lightning Arrestor, and CB on the Westerville No. 2, South Foperville No. 1 terminals, replace the Springdale No. 1 Operating Bus Disconnect and CB and set new Replace Operating Bus Section 1-3 Sect. 3 GOO, Rebuild Operating Bus Section No. 3, Customer new Operating Bus Sect. No. 2 cables for new control house, Remove Transformer No. 2, Sect. 3 and Customer new Operating Disconnect, Replace 88KV pole devices and associated post junction boxes for the following terminals: Housework No. 2, South Foperville No. 1, Springdale No. 1, Springdale Bus Tie, and Bus Disconnects. Close 88KV loops in Bay 1S, to connect 88KV Cap Bank-1 88KV GOO to 88KV Inspection Bus. Prepare TA meter service line from 88KV to 88KV, Remove cable between TA meter cabinet and TA station service transformer.

APPROX CLEARING TIME PERMIT
 Day and Date NOV 03 2019 Time 14:16 Contact Number 409-908-6360
 Issued By [Signature] to [Signature]

Time	Location	DETAILS OF BLOCKING/SWITCHING
0702	888684284	CLOSE TRAN 1-2 TIE (1424-N.O.) 88KV MOLBAR VIA SCADA
0705	WESC	OPEN BRE1 1 88KV CB VIA SCADA
0717	8113284536	OPEN WESC 1 (148) 88KV AB & RT <small>Control House, Station 780-301-0589</small>
0718	8886848526	CLOSE MTRU TAP 2 (1441-N.O.) 88KV MOLBAR VIA SCADA
0711	WESC	OPEN SFOG 1 88KV CB VIA SCADA

Operator Review:
 Cleared by [Signature] Closed by [Signature] Time 14:17 Date DEC 2 3 2019
 Also see permits: C18-02483, 19-07664, 19-02558, 19-02528, 19-07274, 19-07276, 19-02504, 19-07322, 19-02505, 19-02501

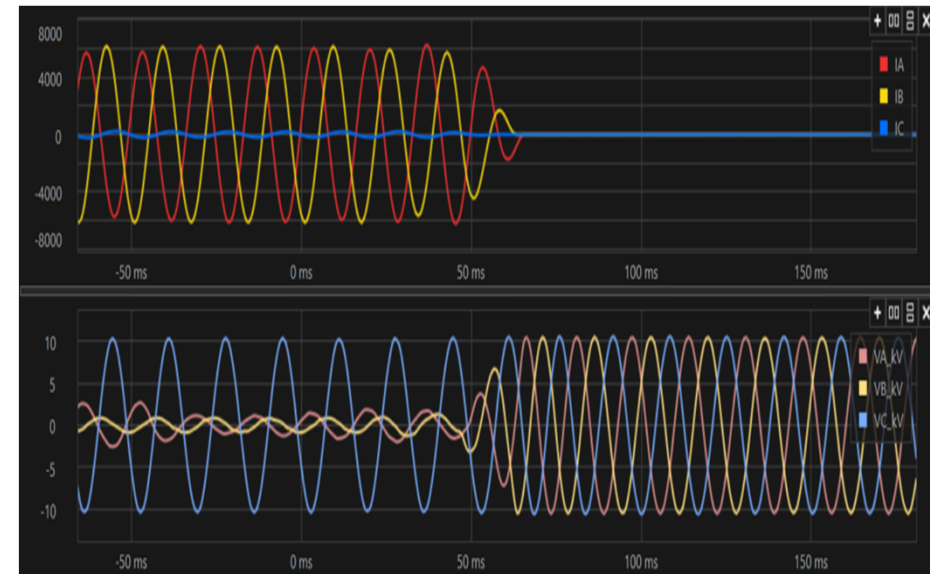
- Heavily rebuilt & strengthened physical plant
- ~50% penetration of microprocessor relays
- Primitive “smart” devices
- No automation
- People-dependent
 - Manual switching / paper permits
 - Reactive to failed equipment
 - Engineer calculated fault locations
 - Isolated voltage control



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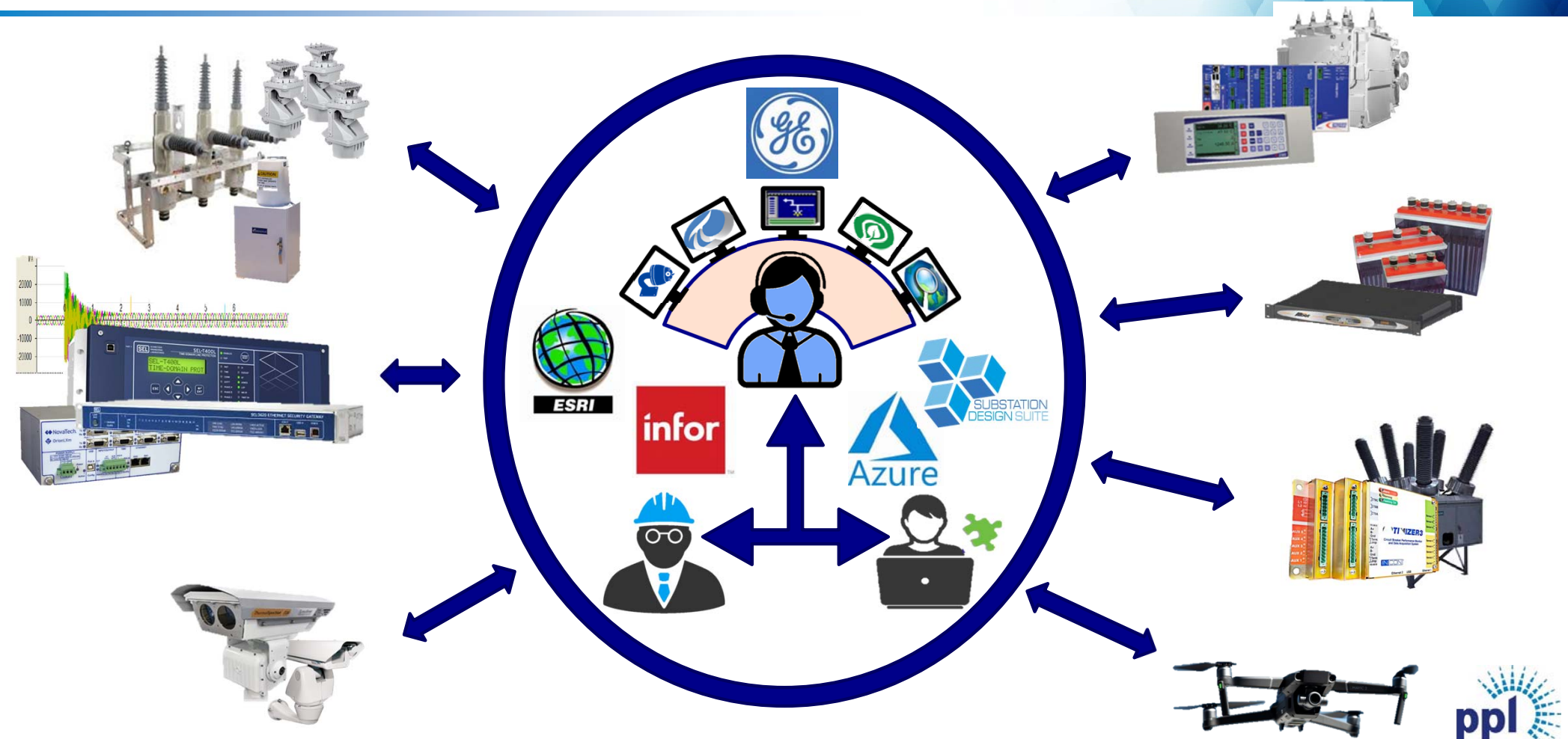
Elements of the Future Transmission Grid

- 100% smart relays & devices
- Single connectivity, geo-spatial, & engineering model
- Predict all failures before they occur
- Automated operations based on real-time data feeds into TMS
- Grid-enhancing technologies
 - Smart Wires
 - Asset Health Monitoring on every asset class
 - *Dynamic Line Monitoring*
 - Traveling Wave Relays



High Resolution Waveform Data

Enabler: Centralized Platforms



What is DLR?

System of line sensors installed to measure conductor and environmental real time data. The data can then be used for asset health algorithms and real-time operation for determining a real time rating for the line.

■ Static Line Ratings

Assumes:

- Wind speed
- Ambient Temp
- Solar Radiation
- 2 Seasons (Summer & Winter)

Conservatively Calculates Ratings

No way to trend field conditions or health

■ Dynamic Line Ratings

Measures:

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

Provides Accurate Real Time Ratings

Allows for Forecasted Ratings

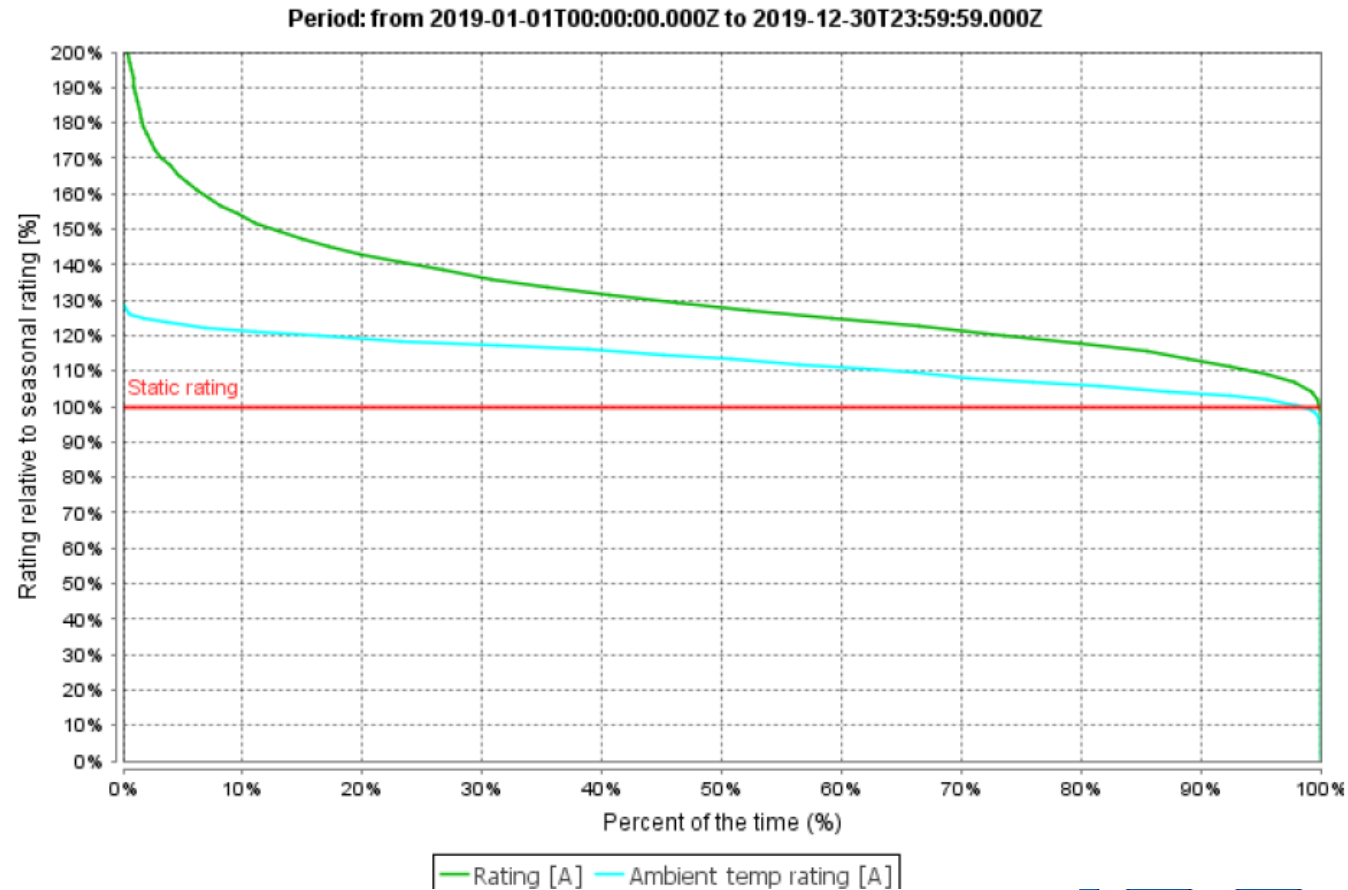
Measures Conductor Health



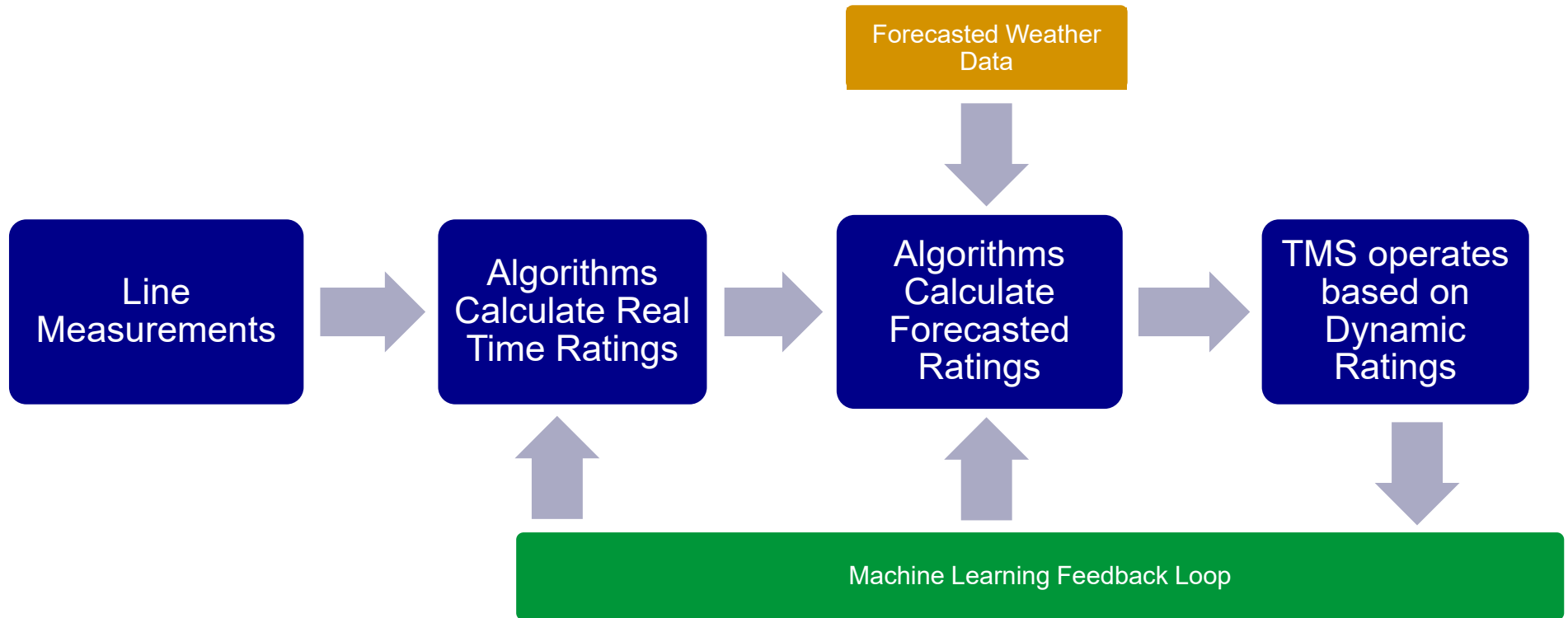
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Potential Ratings Gain

- Used historical temperature and wind speed to estimate the impact of the dynamic lines ratings system
- Based on calculated conductor temperature
- Expected average ratings gain of almost 30%
- Actual rating increase incorporating the real time conductor data is expected to be greater than the estimated ratings using historical data



Dynamic Line Ratings Process

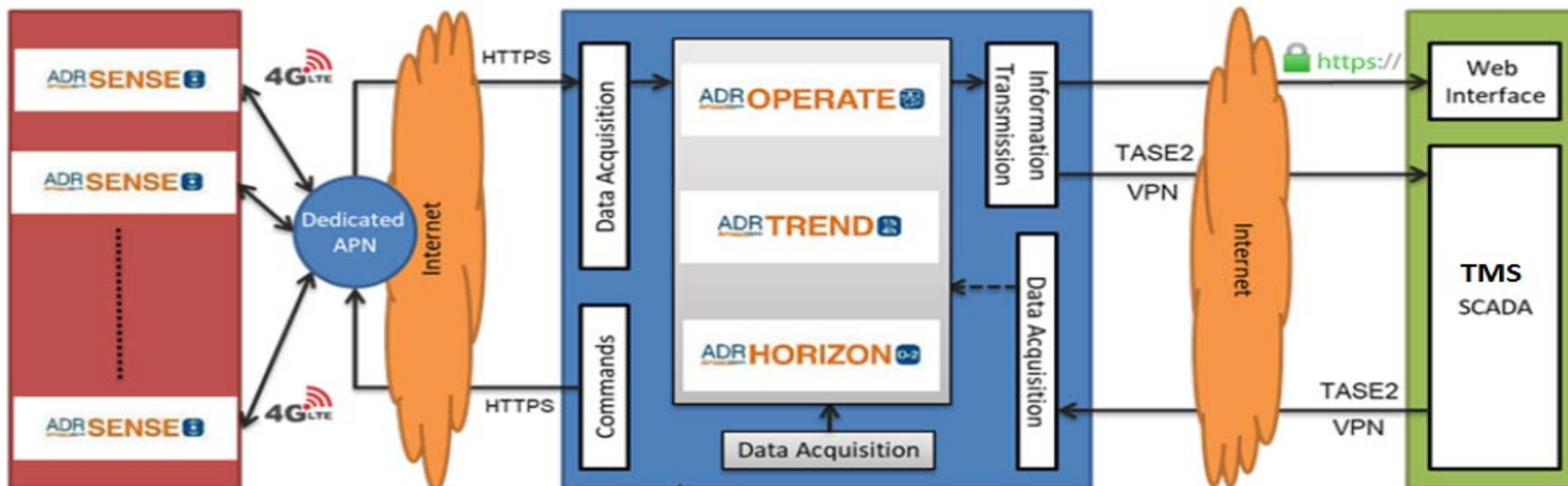


System Overview

Ampacimon
Smart solutions for a smarter grid

Sensors on T-lines

Virtual Server in Cloud Environment



- 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

Next Steps

- Deploying DLR on Juniata-Cumberland & Harwood-Susquehanna lines. We consider the installation of the sensors as permanent for the life of the line.
- Work with PJM to fully utilize available line capacity
- Continue to seek additional lines to install the technology on