Ampacimon

Smart solutions for a dynamic grid

Accelerating the energy transition with technology solutions for critical transmission and distribution assets

Agenda

1. About Ampacimon
2. DLR Technology – How It Works
3. Applications of DLR

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Ampacimon
Smart solutions for a dynamic grid

AMPACIMON IN SHORT

High-End Sensors + High-End Analytics.....

Capacity Optimization & Condition Monitoring

& Predictive Asset Health in OHLs, UGCs and other assets

- Founded in 2010
- Atlanta, USA
  Liege, Belgium
  Madrid, Spain
- 70 Employees
- Deployments in 30+ utilities in 25+ countries
- 130+ Active DLR Deployments
- ISO 9001 certified

SHAREHOLDERS

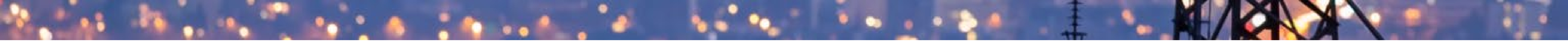
Founders and employees

noshaq

GESVAL s.a.

creos

korys
Invest. Inspire.



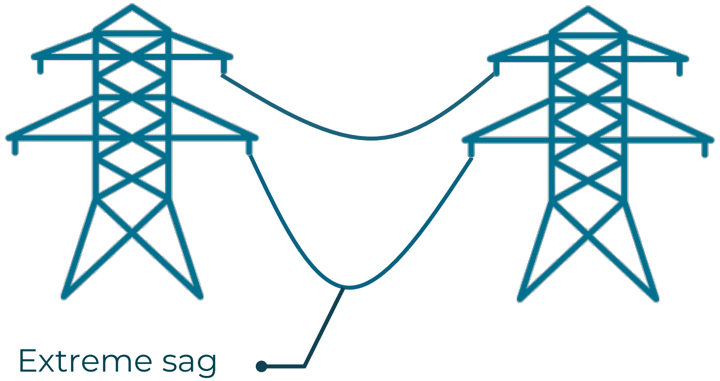
Most Transmission Lines are rated significantly less than their true capacity because they lack visibility on real time conditions

Constrained Capacity

Aging Asset Infrastructure

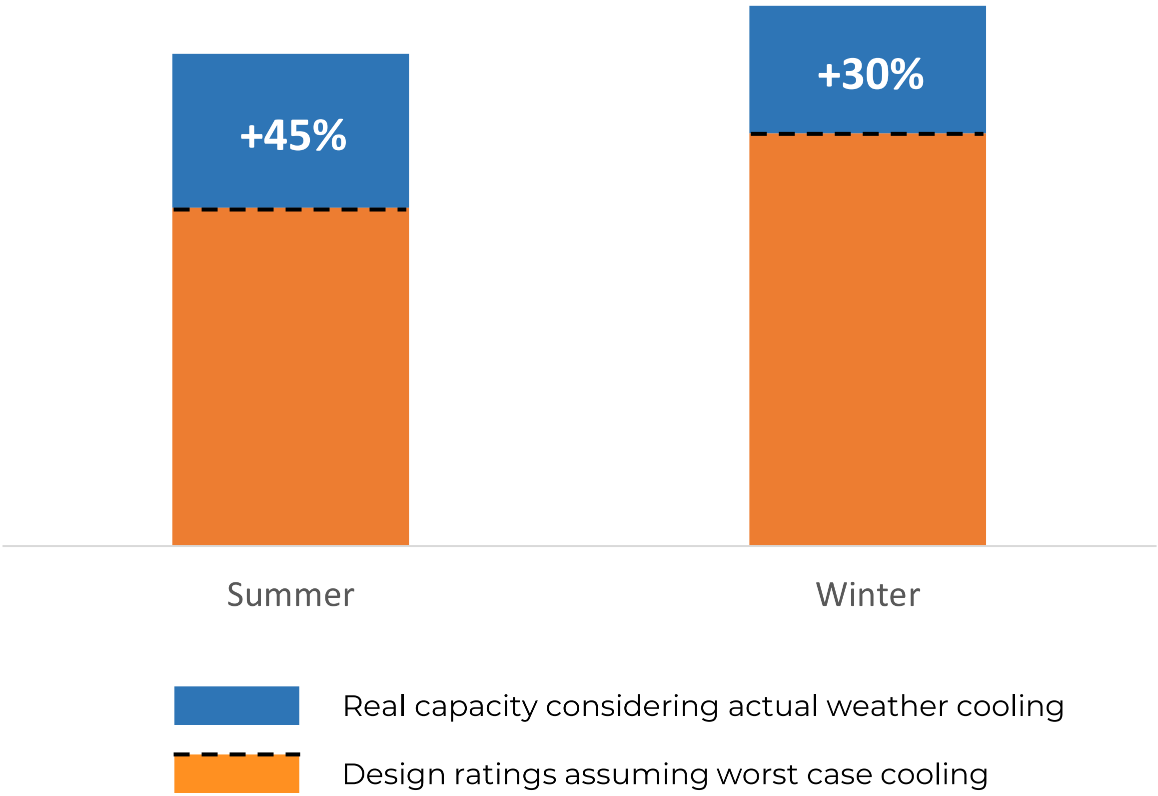
Grid Reliability

- Power line current capacity **depends** technical design of the cables **but are** drastically **affected by weather conditions** (temperature, wind etc.)
- Lack of visibility on external elements typically force grid operators to **design line ratings** assuming "worst conditions"
- Current **naturally heats up** power lines, which, when overheating, may result in **extreme sag** which may result in cable deteriorating faster or even dangerous situations
- Cold weather or wind can **naturally cool down** the power lines and **increase** their **current capacity** without exceeding maximum sag



Source: *IEEE*

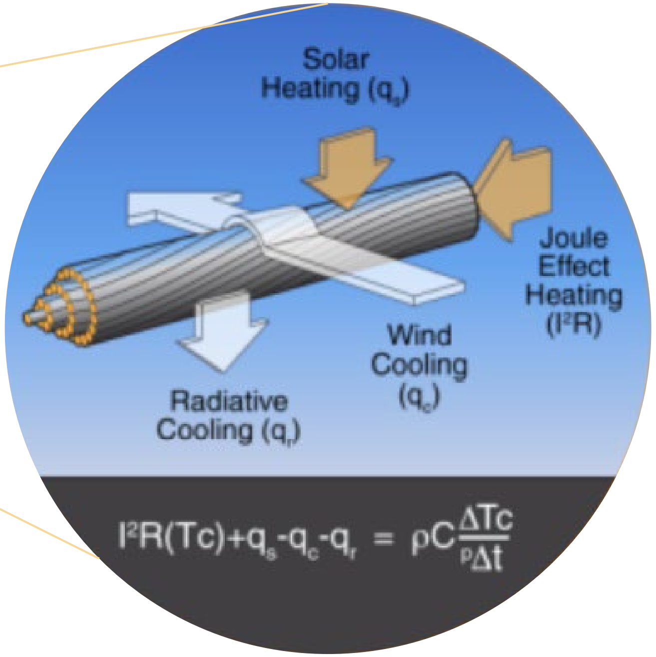
Current carrying capacity depending on weather conditions

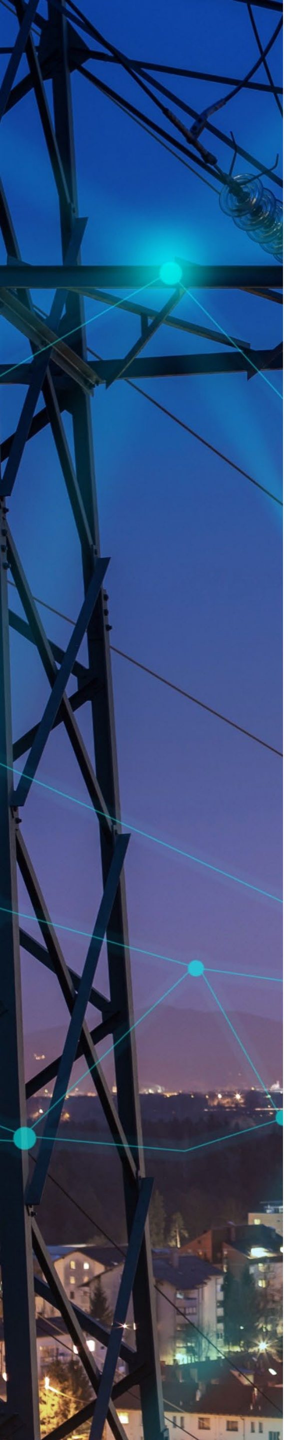


Dynamic Line Rating

How It Works

Transmission Lines Have a Rated Capacity based on maximum conductor temperature or sag





Wind is the key factor to increasing capacity

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%

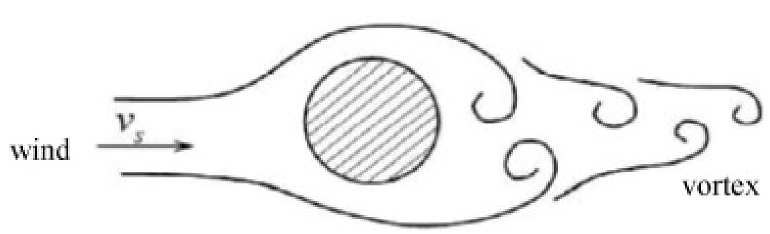
Source: Navigant Consulting, Inc. (Navigant) analysis; data from (7)

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

Measuring Wind Speed

Wind < 2m/s

Vortex-induced vibrations and strouhal equation



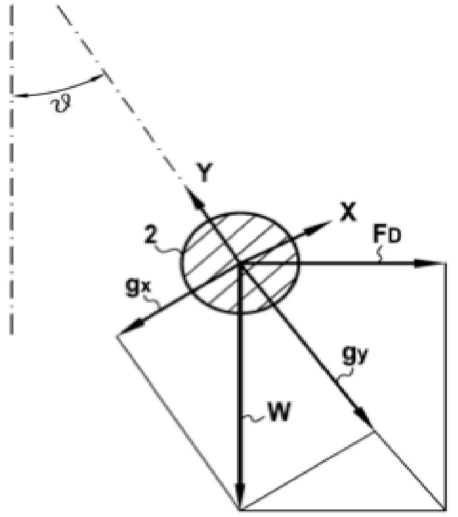
Strouhal number [0,185] St= fD / U

- f : oscillation wind frequency
- D : Line diameter
- U : Flow velocity (perpendicular wind)

- High Accuracy at **low speeds (Aeolian vibrations)**
- Measured as a "span-value" exactly at the **conductor/line level (not a single-spot location)**

Wind > 2m/s

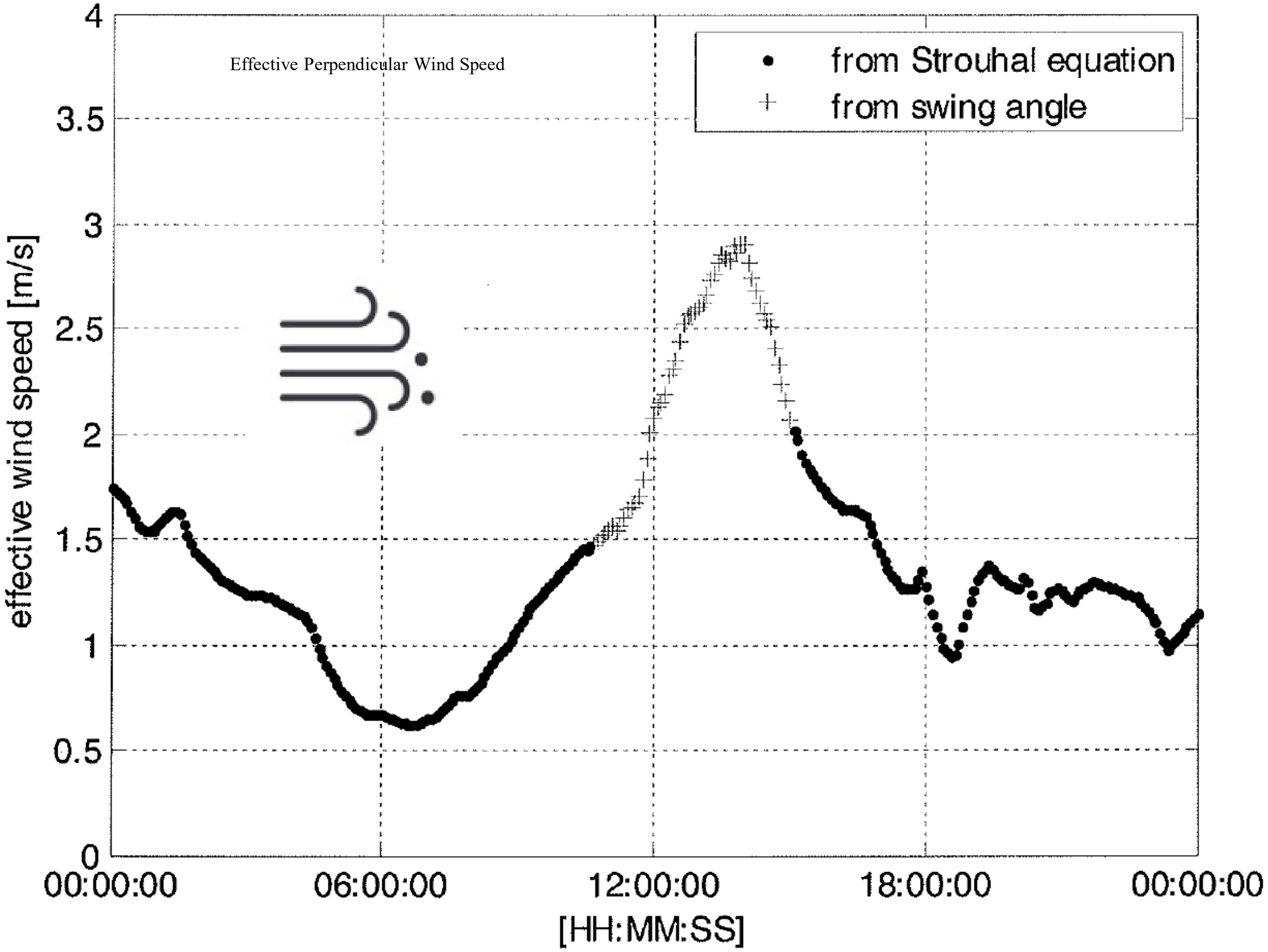
Swing Angle

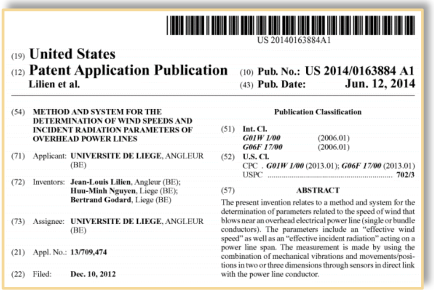


$$V_w = \sqrt{\frac{p_w tan\Phi_C}{\rho g}}$$

$$p_w = \frac{}{1/2 C_D \rho_{air} d_C}$$

Measuring Wind Speed, Continued





US 20140163884A1

(19) **United States**
(12) **Patent Application Publication**
Lilien et al.

(10) **Pub. No.: US 2014/0163884 A1**
(43) **Pub. Date: Jun. 12, 2014**

(54) **METHOD AND SYSTEM FOR THE DETERMINATION OF WIND SPEEDS AND INCIDENT RADIATION PARAMETERS OF OVERHEAD POWER LINES**

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(72) Inventors: **Jean-Louis Lilien**, Angleur (BE); **Huu-Minh Nguyen**, Liege (BE); **Bertrand Godard**, Liege (BE)

(73) Assignee: **UNIVERSITE DE LIEGE**, ANGLEUR (BE)

(21) Appl. No.: **13/709,474**

(22) Filed: **Dec. 10, 2012**

Publication Classification

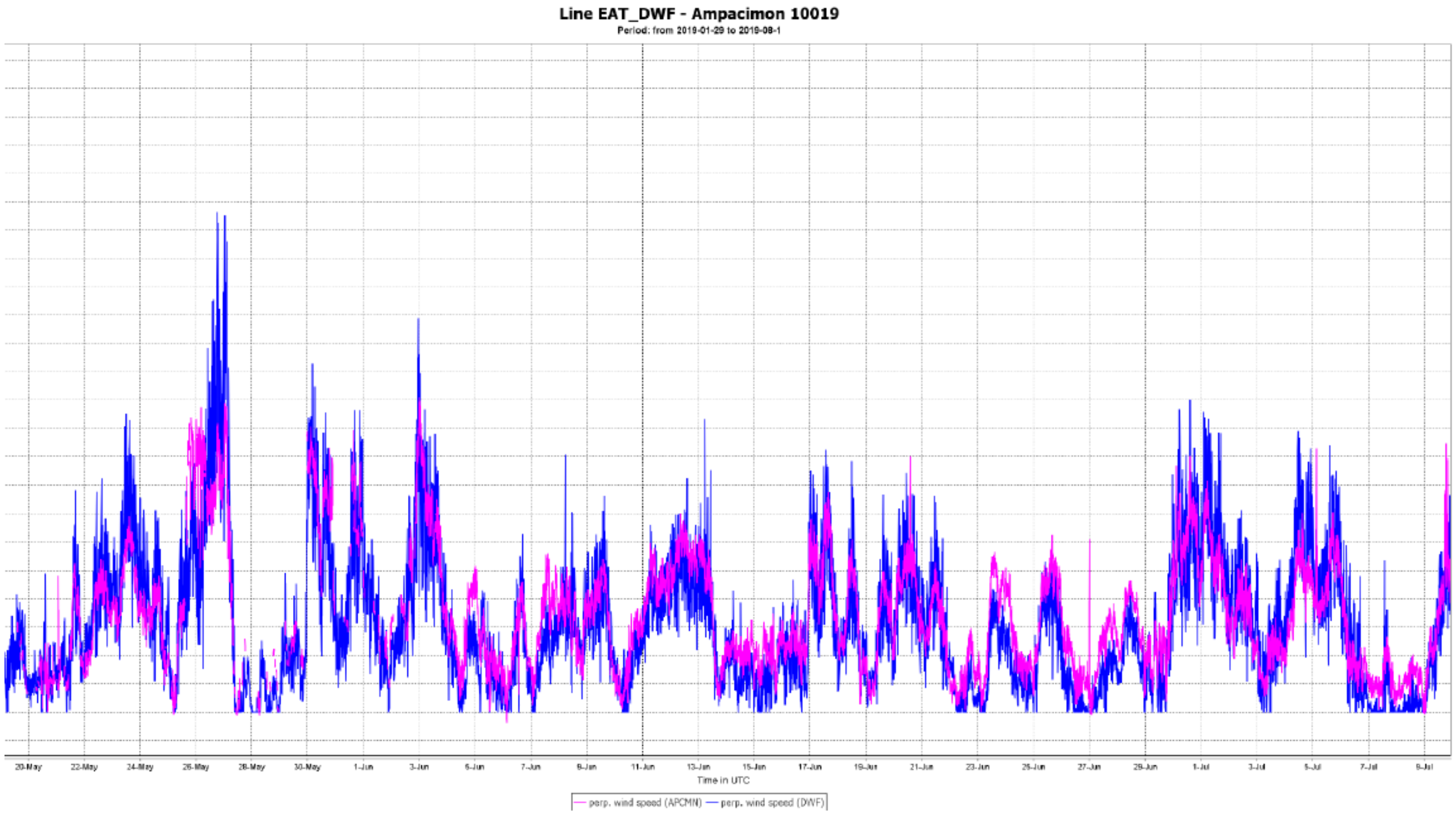
(51) **Int. Cl.**
G01W 1/00 (2006.01)
G06F 17/00 (2006.01)

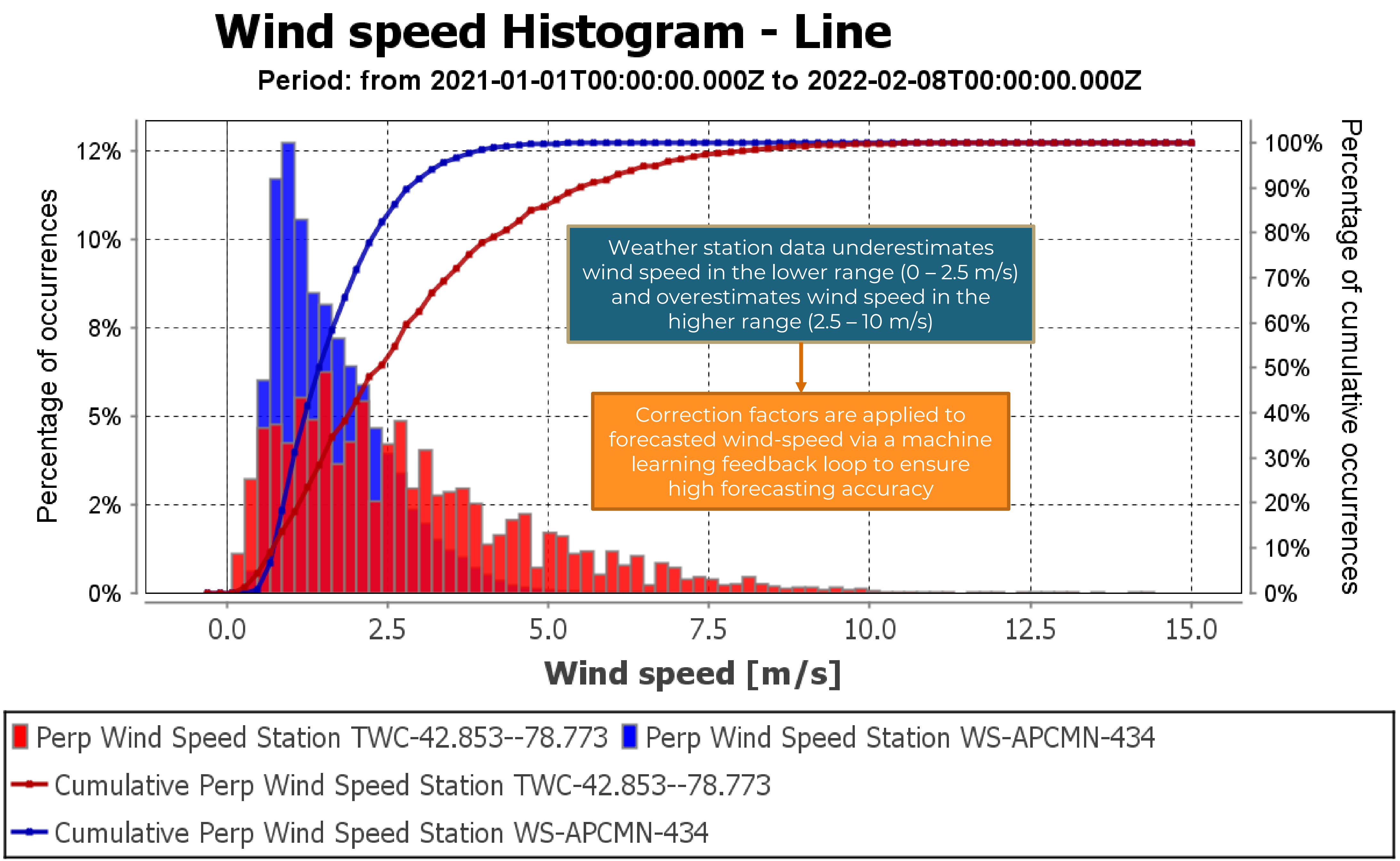
(52) **U.S. Cl.**
CPC . ***G01W 1/00*** (2013.01); ***G06F 17/00*** (2013.01)
USPC **702/3**

(57) **ABSTRACT**

The present invention relates to a method and system for the determination of parameters related to the speed of wind that blows near an overhead electrical power line (single or bundle conductors). The parameters include an "effective wind speed" as well as an "effective incident radiation" acting on a power line span. The measurement is made by using the combination of mechanical vibrations and movements/positions in two or three dimensions through sensors in direct link with the power line conductor.

Wind Speed Measurement Validation

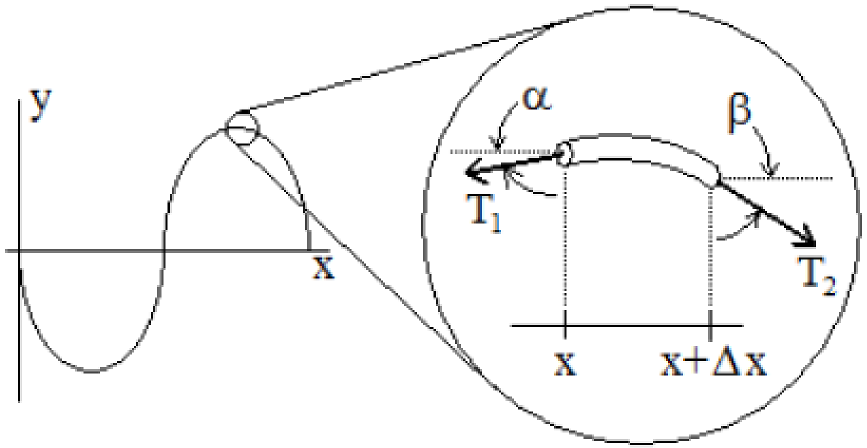




Wind speed Histogram - Line
Period: from 2021-01-01T00:00:00.000Z to 2022-02-08T00:00:00.000Z
Percentage of occurrences
12%
10%
8%
5%
2%
0%
Percentage of cumulative occurrences
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
2.5
5.0
7.5
10.0
12.5
15.0
Wind speed [m/s]
Weather station data underestimates wind speed in the lower range (0 – 2.5 m/s) and overestimates wind speed in the higher range (2.5 – 10 m/s)
Correction factors are applied to forecasted wind-speed via a machine learning feedback loop to ensure high forecasting accuracy
Perp Wind Speed Station TWC-42.853--78.773
Perp Wind Speed Station WS-APCMN-434
Cumulative Perp Wind Speed Station TWC-42.853--78.773
Cumulative Perp Wind Speed Station WS-APCMN-434

Vibration-Based Sag

$$sag \approx \frac{\rho g a^2}{8H}$$



<u>Horizontal Component of Tension is Constant, “H”</u>

$$T_{1x} = T_1 \cos(\alpha) \approx H$$
$$T_{2x} = T_2 \cos(\beta) \approx H$$

<u>Vertical Component of Tension is proportional to mass and acceleration</u>

$$\sum F_Y = -T_{2y} - T_{1y} = -T_2 \sin(\beta) - T_1 \sin(\alpha) = (\rho g dx) a_c \approx \rho g dx \frac{\partial^2 u}{\partial t^2}$$

<u>Combining Vertical and Horizontal Components</u>

$$-\frac{\rho dx}{H}\frac{\partial^2 u}{\partial t^2} = \frac{T_2 \sin(\beta)}{T_2 \cos(\beta)} + \frac{T_1 \sin(\alpha)}{T_1 \cos(\alpha)} = \tan(\beta) + \tan(\alpha)$$

Substitutions and Solving

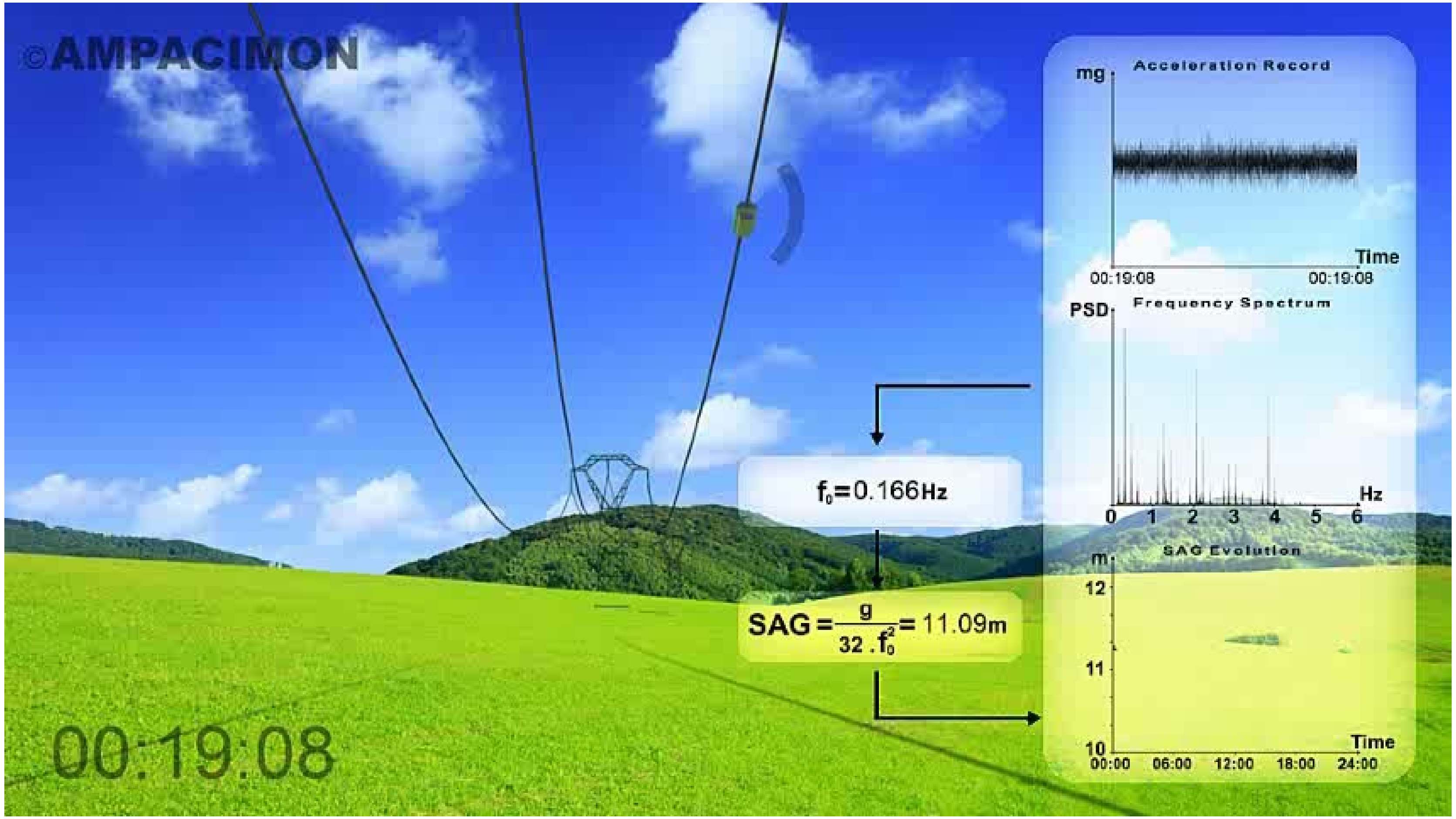
$$f_k = \frac{\omega_k}{2\pi} = k\,\frac{1}{2a}\sqrt{\frac{H}{\rho}}$$

<u>Combining with Sag Formula where k=1</u>

$$sag = \frac{g}{32 f_1^2}$$

→ We only need to track changes in the fundamental vibration frequency to measure sag!!

Vibration Based Sag



Accuracy of +/- 20 cm regardless of conductor height

Mean Conductor Temperature

Accurate Sag → Accurate Mean Conductor Temperature

The length of overhead line’s conductor expands because of thermal and elastic expansion

(8f2 / 3L2) - (pL2 / 8f ES) - aT = Cte

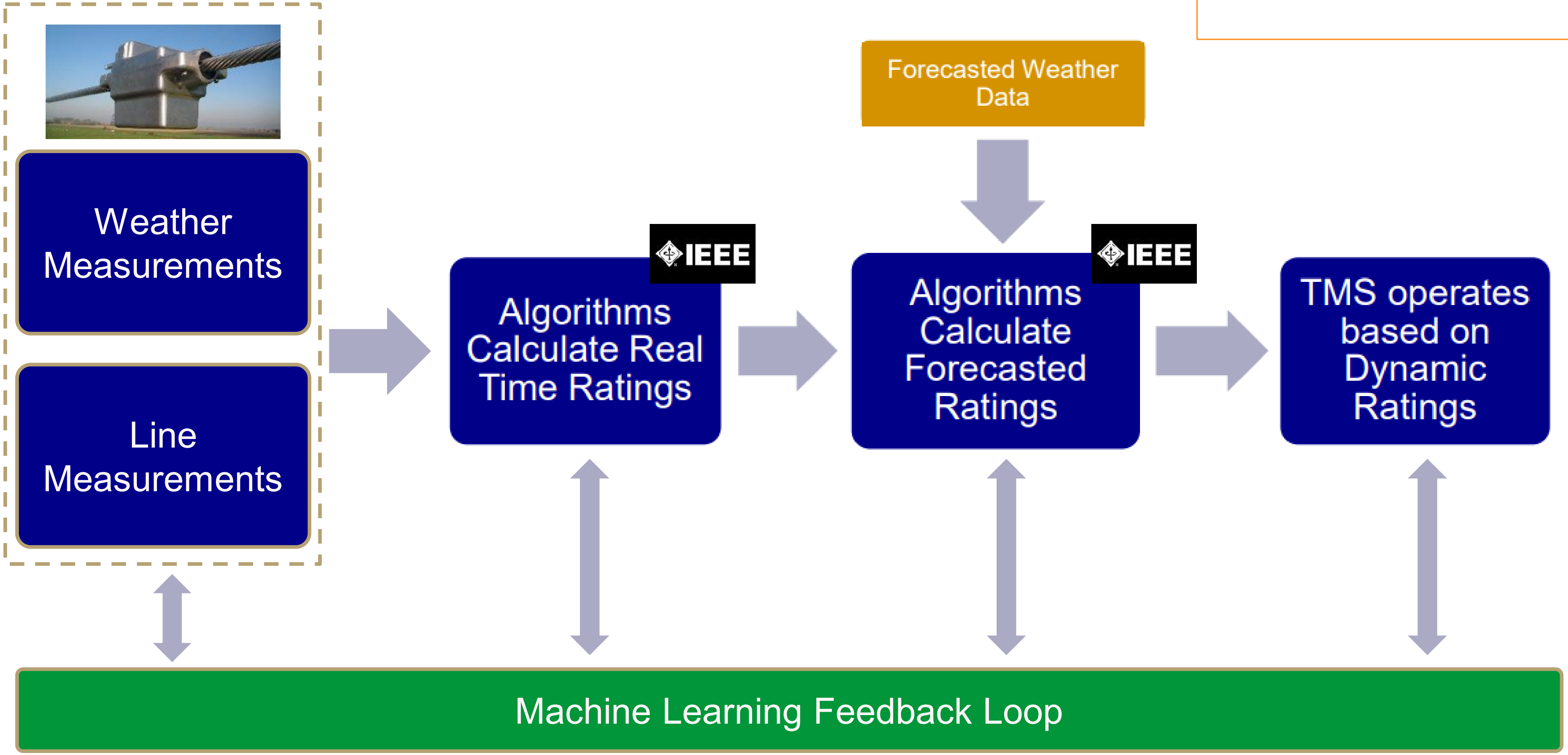
a - thermal expansion coefficient
E – Young modulus
S – conductor cross section
p – conductor weight per meter
L - rulling span lenght

Sag

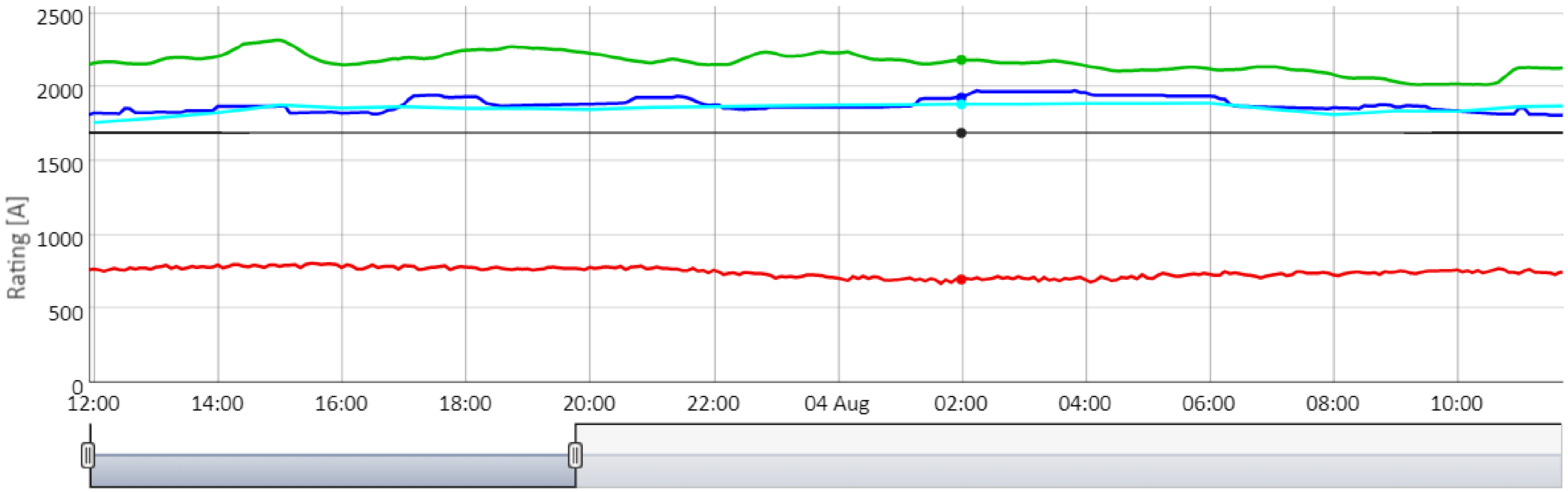
Temperature

Dynamic Line Ratings Process

Machine learning with wind measurements allow **for 98% confidence interval** capacity forecast while retaining significant gains



Ratings Output Example



Line information

Maximum temperature: 180°C

Use Maximum Temperature Limit: Yes

Use Maximal Sag Limit: No

ADR OPERATE

ADR TREND

ADR HORIZON

Date: 2021/08/04 02:00

- Rating: 2188 A
- Load: 699 A
- Static rating: 1693 A
- Forecast 1h: 1933 A
- Forecast 24h: 1887 A

Ratings are calculated every 5 minutes and are passed onto the utility's EMS via REST-API, DNP3 Integration of our SaaS solution, or On-Premise integration

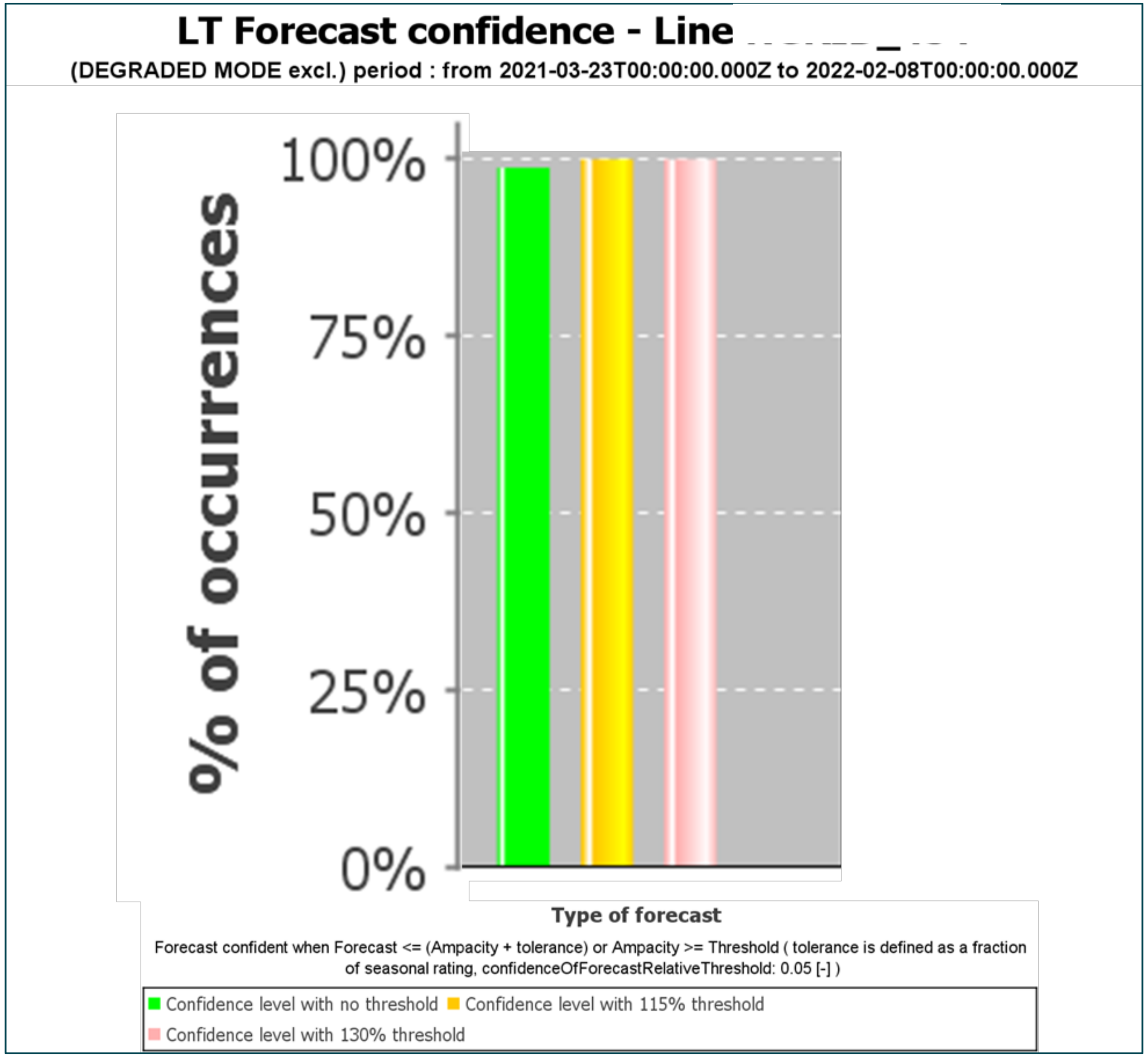
Accuracy And System Availability

>98% Long Term Forecasting Accuracy

- All short-term forecasts are 100% reliable (hours ahead)
- All long-term forecasts are >98% Accurate (Days Ahead)

>97% Data Availability

- DLR sensors are powered by line induction



DLR Systems Can Also Improve Awareness & Reliability

ADR SENSE | ADR SENSE D

WEATHER STATION

- AMBIENT TEMPERATURE
- SOLAR RADIATION

VIBRATION | MEAN CONDUCTOR TEMPERATURE | EFFECTIVE WIND SPEED | SAG + TENSION | CURRENT

UTILITY

- CONDUCTOR PARAMETERS

ADR OPERATE | ADR HORIZON D-2 | ADR TREND 1h 4h | ADR TRANSIENT | ADR Ampacimon | ADR ICE | ADR HEALTH

DYNAMIC LINE RATING

→ REAL-TIME CAPACITY GAIN

→ UP TO 72 HOURS CAPACITY FORECAST

→ AAR (10 DAYS FORECAST)

CONDITION MONITORING

→ TEMPERATURE/VIBRATION/SAG MONITORING

→ GALLOPING

→ ICE DETECTION

→ MECHANICAL EVENT DETECTION

PREDICTIVE ASSET HEALTH

→ FATIGUE ANALYSIS

→ STATISTICAL REMAINING LIFE DETERMINATIO

→ CONDUCTOR FLEET BENCHMARKING

→ MAINTENANCE PRIORITIZATION/PLANNING

ADR HEALTH

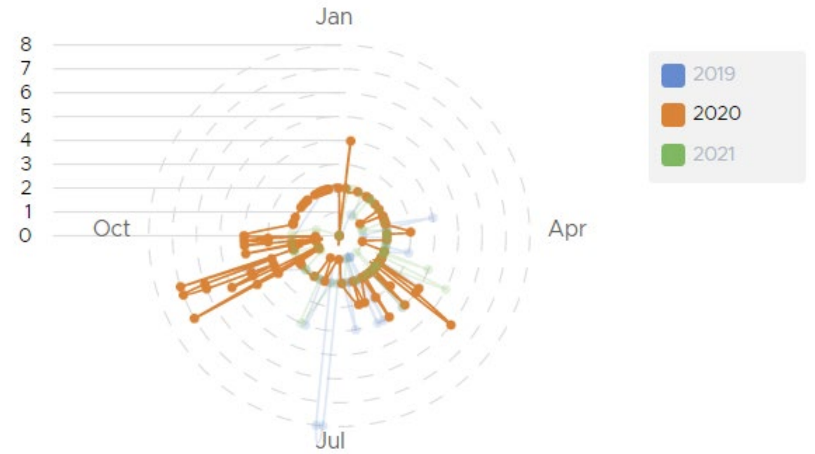
Ampacimon

FILTERS

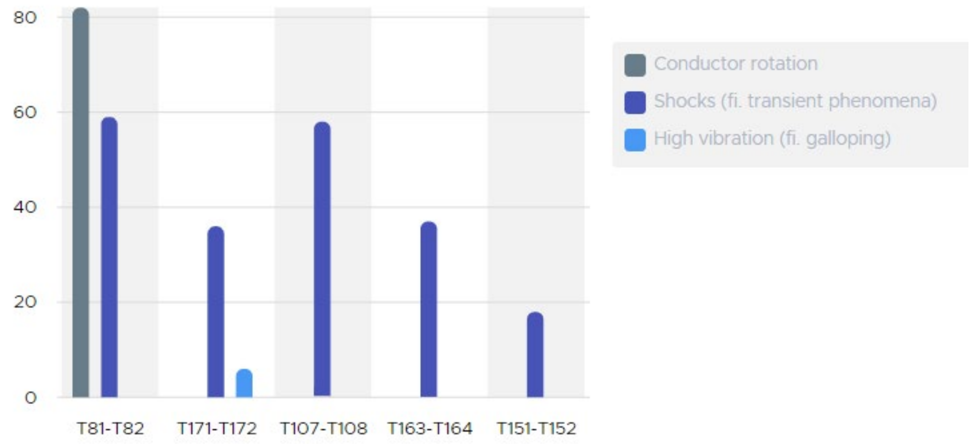
	Lines
○	EU_WEST_L1
○	EU_EAST_L1
○	EU_NORTH_L1
◉	INDIA_L1
○	USA_L1

Index | Events | Time series

• EVENTS



• EVENTS BY SENSORS



Events ⓘ

Conductor rotation × | High vibration (fi. galloping) × | Shocks (fi. transient phenomena) × | Ice × | Fallen conductor × | Anomalous Sag ×

LineId	SpanId	AmpacimonId	EventCode	EventName	FromDate	ToDate	Duration (hh:mm)	Actions
INDIA_L1	T81-T82	274	4	Conductor rotation	27-08-2020 02:20	29-08-2020 12:30	46:10	SHOW
INDIA_L1	T81-T82	274	4	Conductor rotation	29-08-2020 03:10	29-08-2020 03:30	0:20	SHOW
INDIA_L1	T81-T82	274	4	Conductor rotation	29-08-2020 04:25	29-08-2020 04:50	0:25	SHOW

Line-by-Line & Sensor-by-Sensor Historical Event Analysis

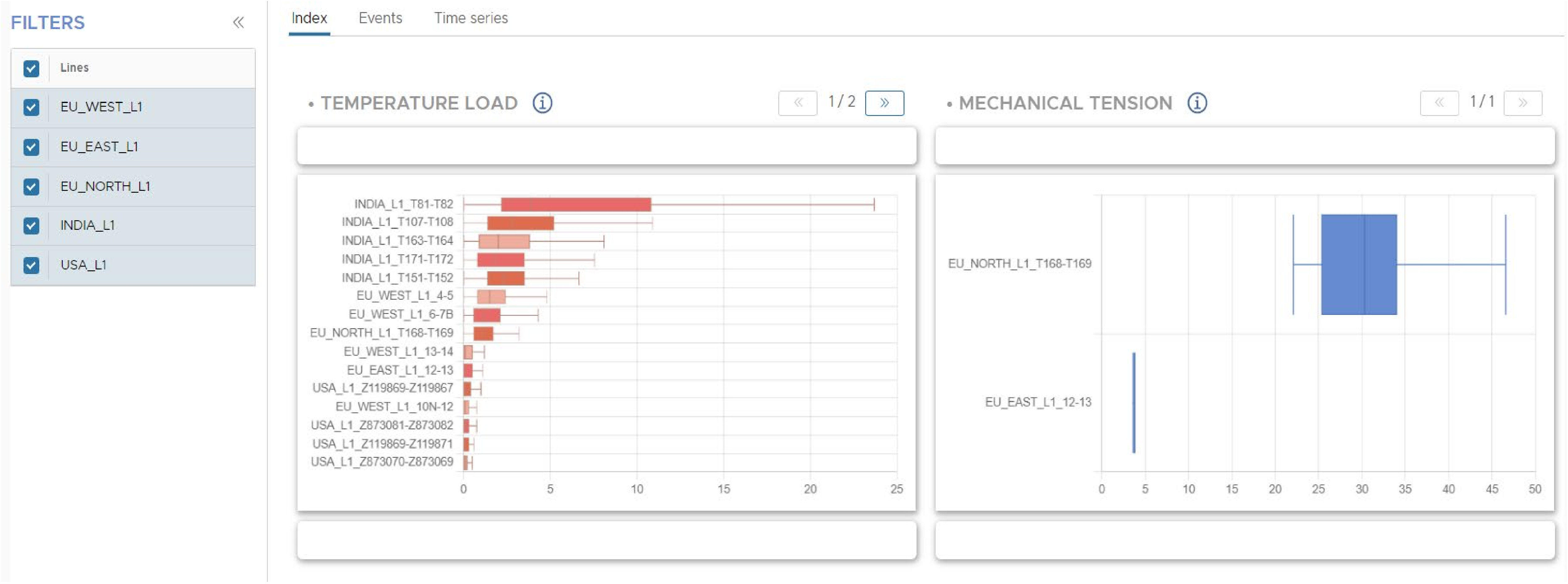
ADR Ampacimon HEALTH

Line-by-Line Analysis and Benchmarking of Conductor Ampacity, Temperature, Sag, Wind

ADR Ampacimon HEALTH

Line-by-Line Analysis and Benchmarking of Conductor Ice, Sag, Tension, Rotation Angle

ADR Ampacimon HEALTH



Fleet Overview and Benchmarking to Plan and Prioritize Maintenance Planning

THANK YOU

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aps
New York Power Authority
isa TRANSELCA
nationalgrid
BC Hydro Power smart

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