Large-Scale DLR Deployment

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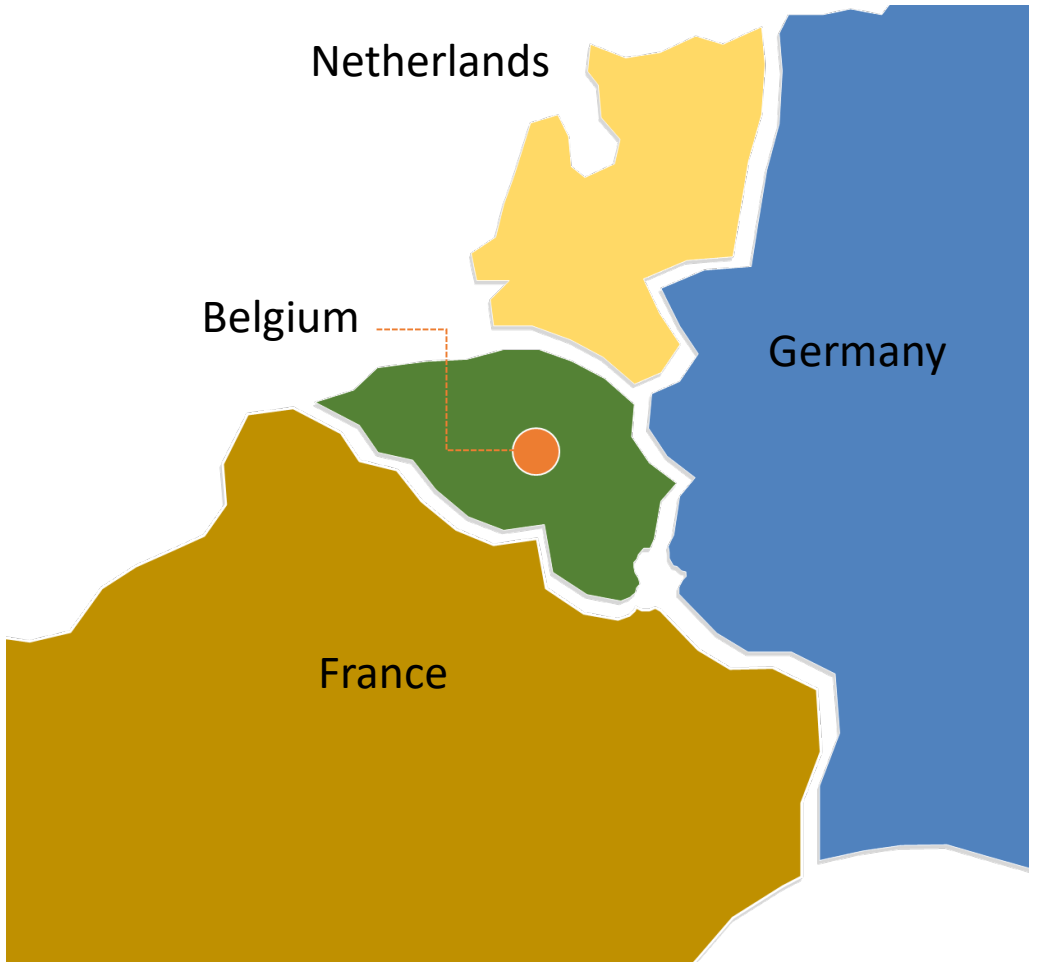
Powering a world in progress

Belgium's Transmission System Operator

Over 8,700 km of transmission lines

13,000 MW peak consumption (Winter)

2-Day Ahead trading market with France and Netherlands



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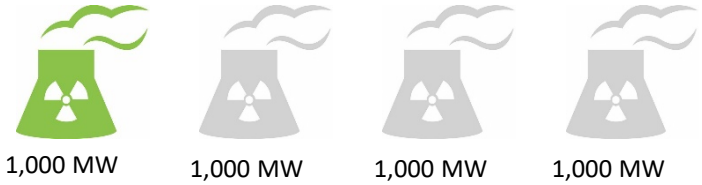
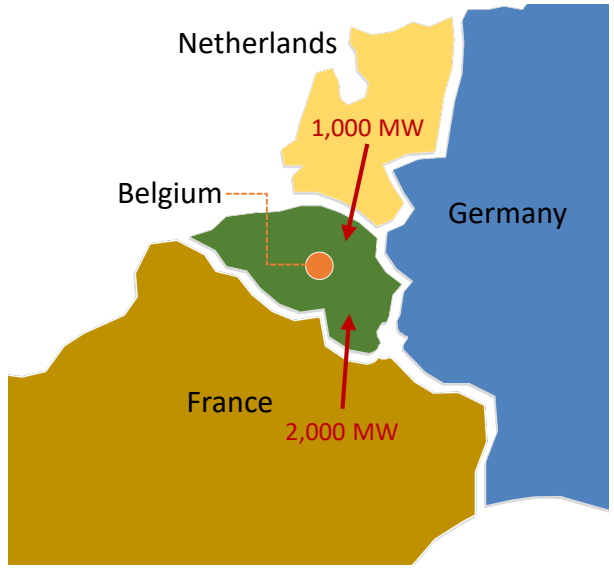
Elia's Challenge



Summer 2014
Elia facing the shutdown of 3 of its 4 nuclear plants due to various technical reasons

The shutdowns represented 3,000 MW in lost generation capacity



Maximum import capacity of 3,000 MW from France and Netherlands

With the imports as a higher risk source, Elia needed to increase it's import transmission capacity by 30% (1,000 MW) and capacity for North-South flows by the winter peak loading time

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DLR Deployment

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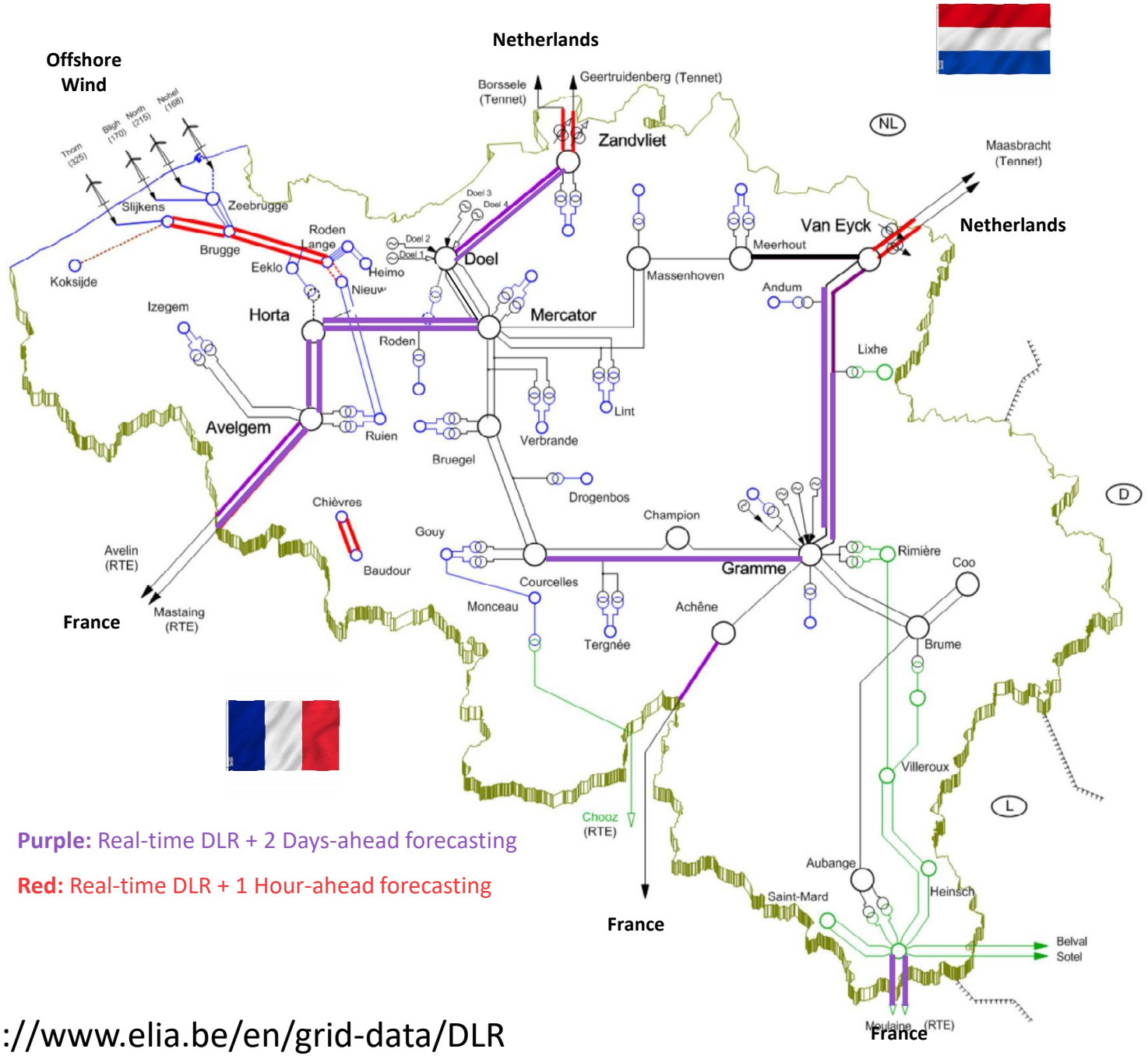
Large-Scale DLR Deployment

35 Lines | 167 Devices | 70 kV - 380 kV



Purple: Real-time DLR + 2 Days-ahead forecasting

Red: Real-time DLR + 1 Hour-ahead forecasting

http://www.elia.be/en/grid-data/DLR

How Ampacimon DLR works

ADR SENSE
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Method of Operation

- 3-Dimensional vibration sensing (100 µG) to measure **line sag** and perpendicular **wind speed** in Realtime
- Powered by current transformer for energy harvesting (no need for battery or solar panel)
- Installs in 15 minutes on deenergized or energized line
- Cellular 4G LTE and Satellite communications sends 5-minute interval data to utility/host for real-time and forecasted DLR using IEEE-738 and CIGRE TB-207
- Realtime Ampacimon HMI + SCADA/EMS Integration through TASE2 and DNP3

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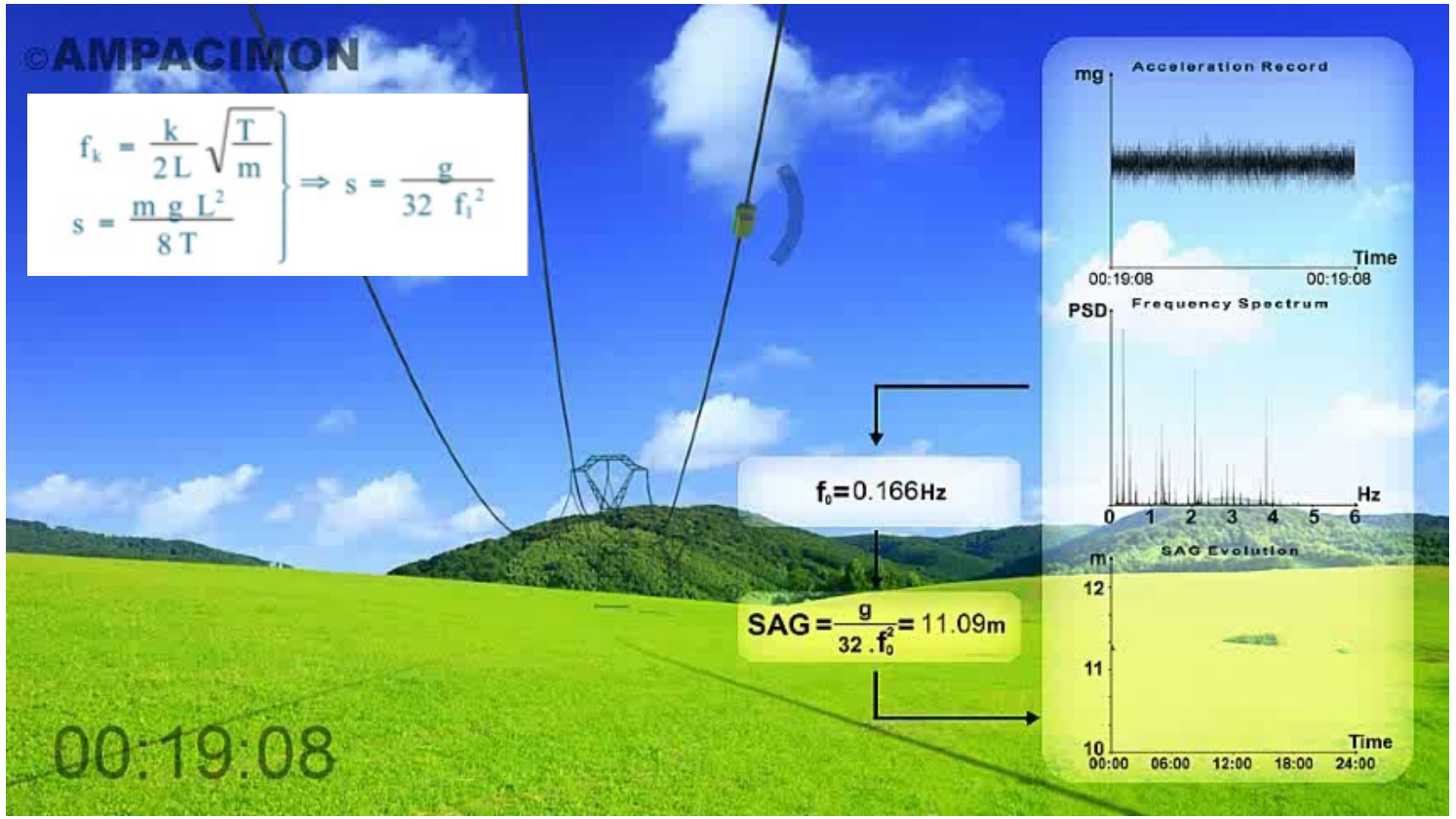
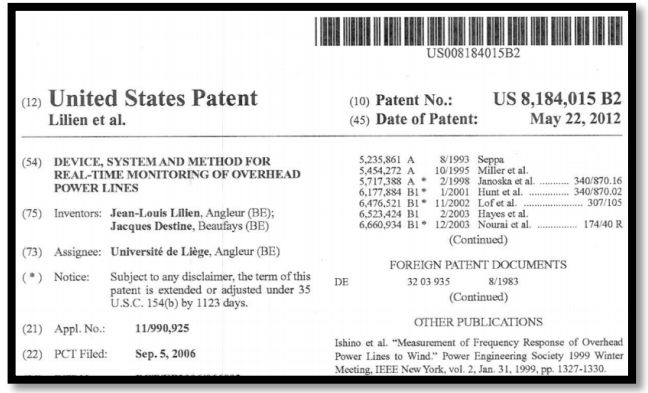
Measurement of Sag





US008184015B2

(12) **United States Patent**
Lilien et al.

(10) **Patent No.: US 8,184,015 B2**
(45) **Date of Patent: May 22, 2012**

(54) **DEVICE, SYSTEM AND METHOD FOR REAL-TIME MONITORING OF OVERHEAD POWER LINES**

(75) Inventors: **Jean-Louis Lilien**, Angleur (BE); **Jacques Destine**, Beaufays (BE)

(73) Assignee: **Université de Liège**, Angleur (BE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1123 days.

(21) Appl. No.: **11/990,925**

(22) PCT Filed: **Sep. 5, 2006**

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Ishino et al. "Measurement of Frequency Response of Overhead Power Lines to Wind." Power Engineering Society 1999 Winter Meeting, IEEE New York, vol. 2, Jan. 31, 1999, pp. 1327-1330.

+/- 1% Sag Measurement Accuracy

NO Calibration and DOES NOT need any external data or conditions such as span geometry, load, weather, topology, suspension movement, creeping or even calibration.

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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

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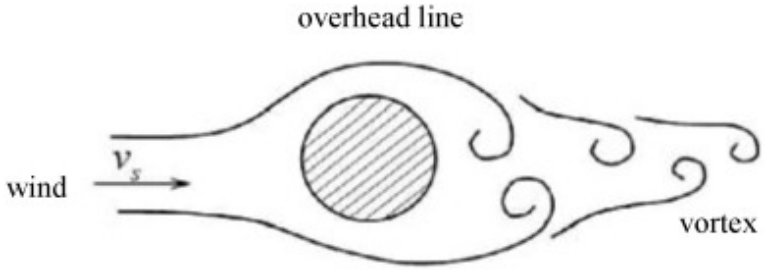
Measurement of Effective Wind Speed

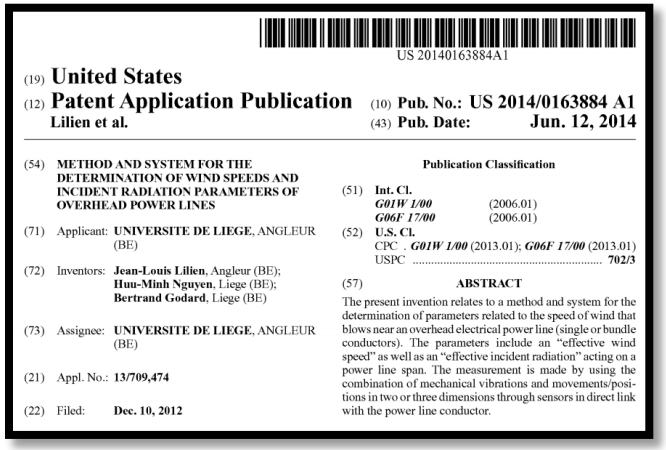
Wind < 2m/s

Aeolian Vibration; 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)



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(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**

(71) Applicant: **UNIVERSITE DE LIEGE**, ANGLEUR (BE)

(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

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G06F 17/00 (2006.01)

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

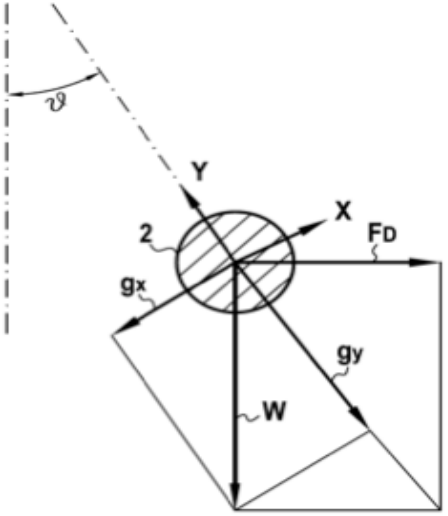
(57) **ABSTRACT**

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.

- 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



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

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

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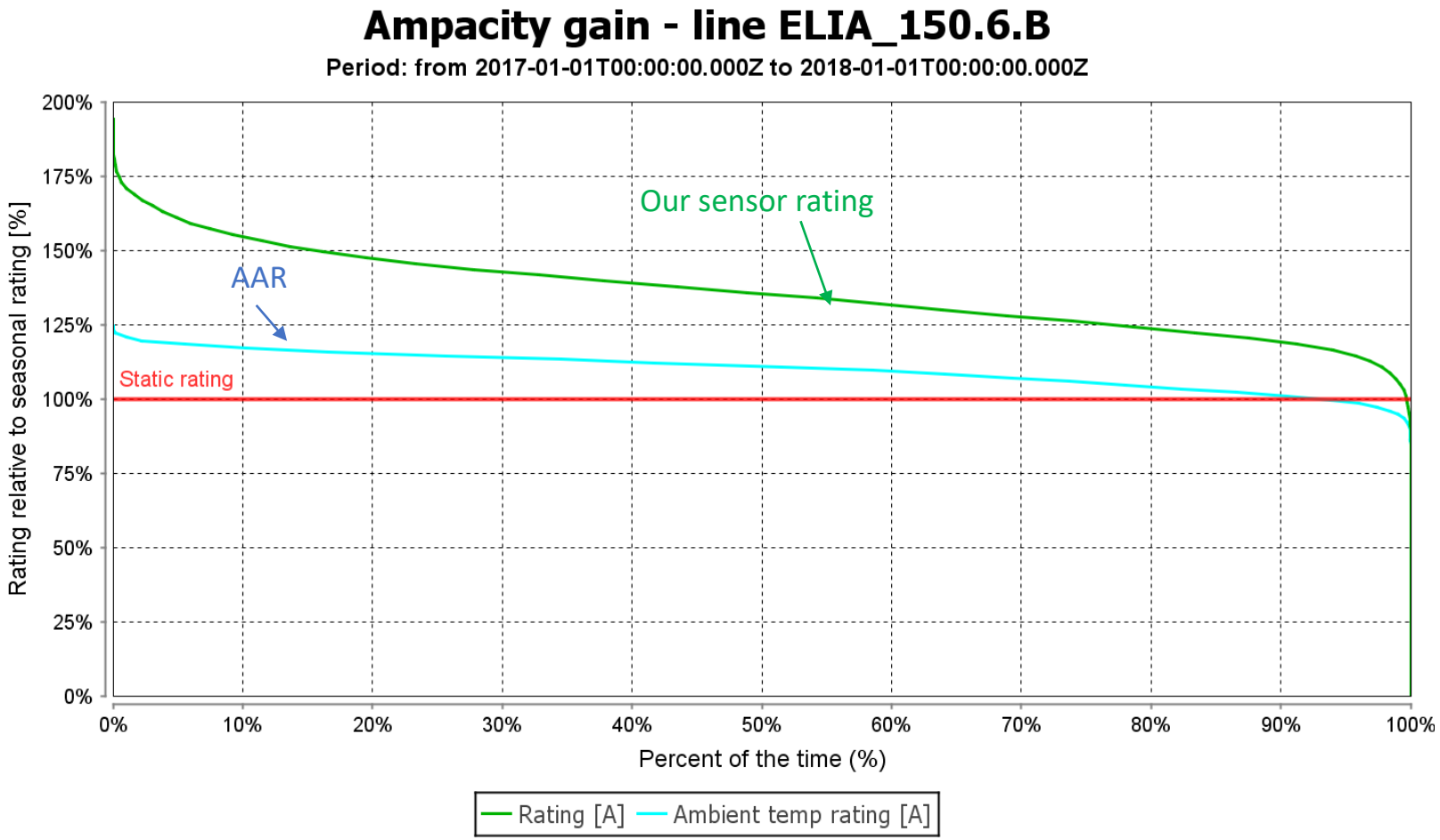
AAR gives less gain



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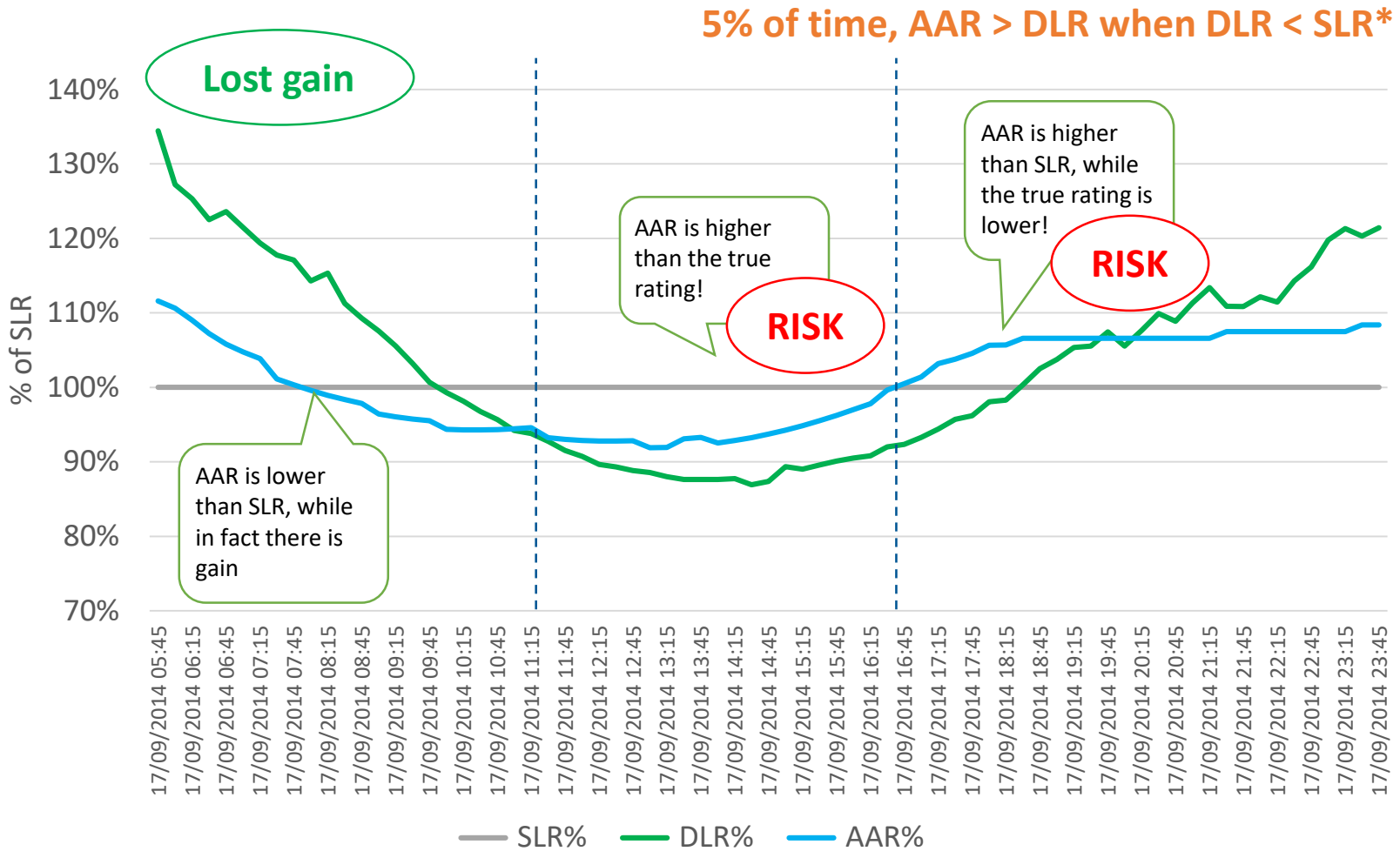
AAR exacerbates risk by 5%



* Based on data set from 2014-2018

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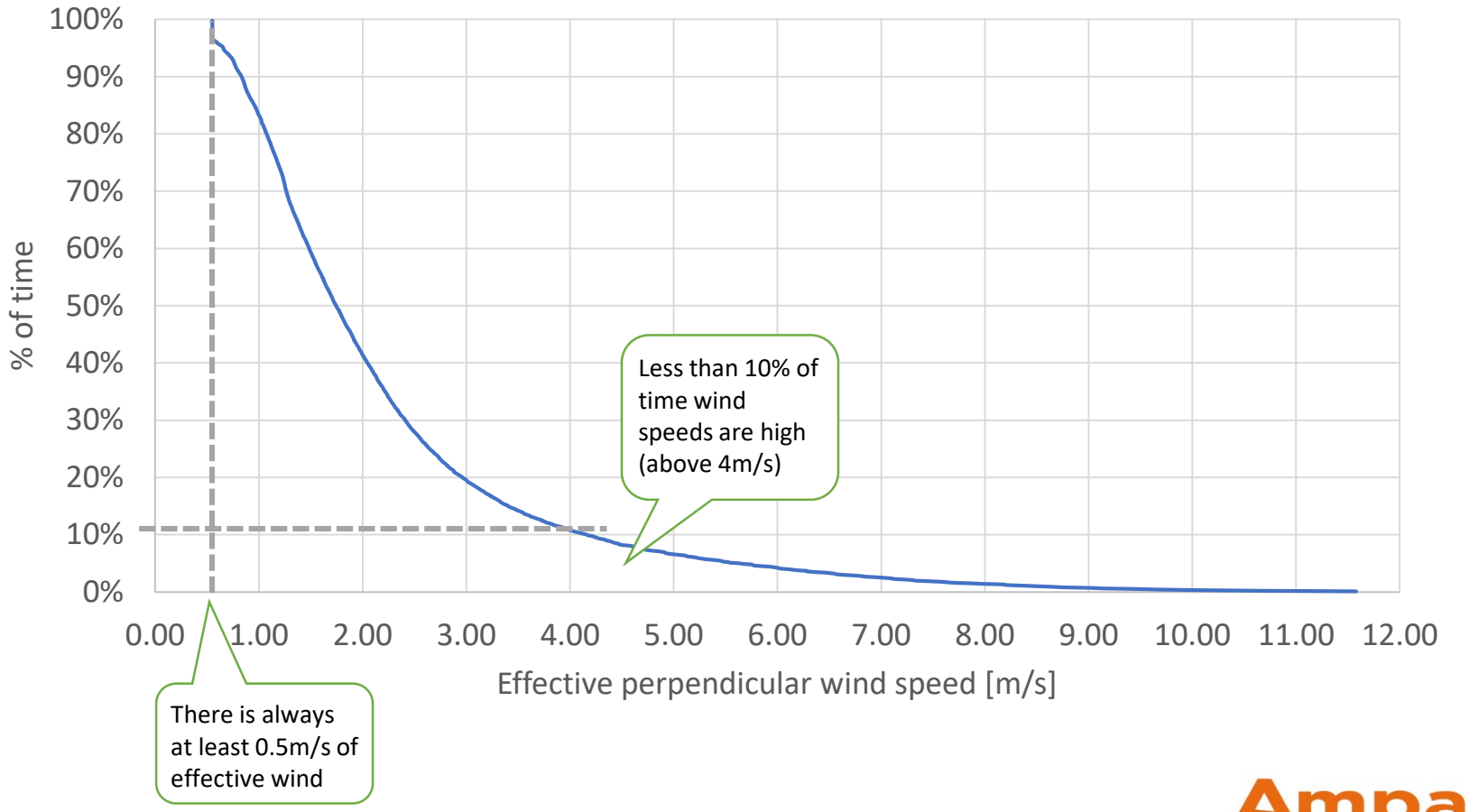
Wind speed at line affecting DLR is less than 4m/s most of the time

- **AAR does not capture ANY wind effect**
- **Weather-based models cannot estimate accurately local wind speeds in this range**



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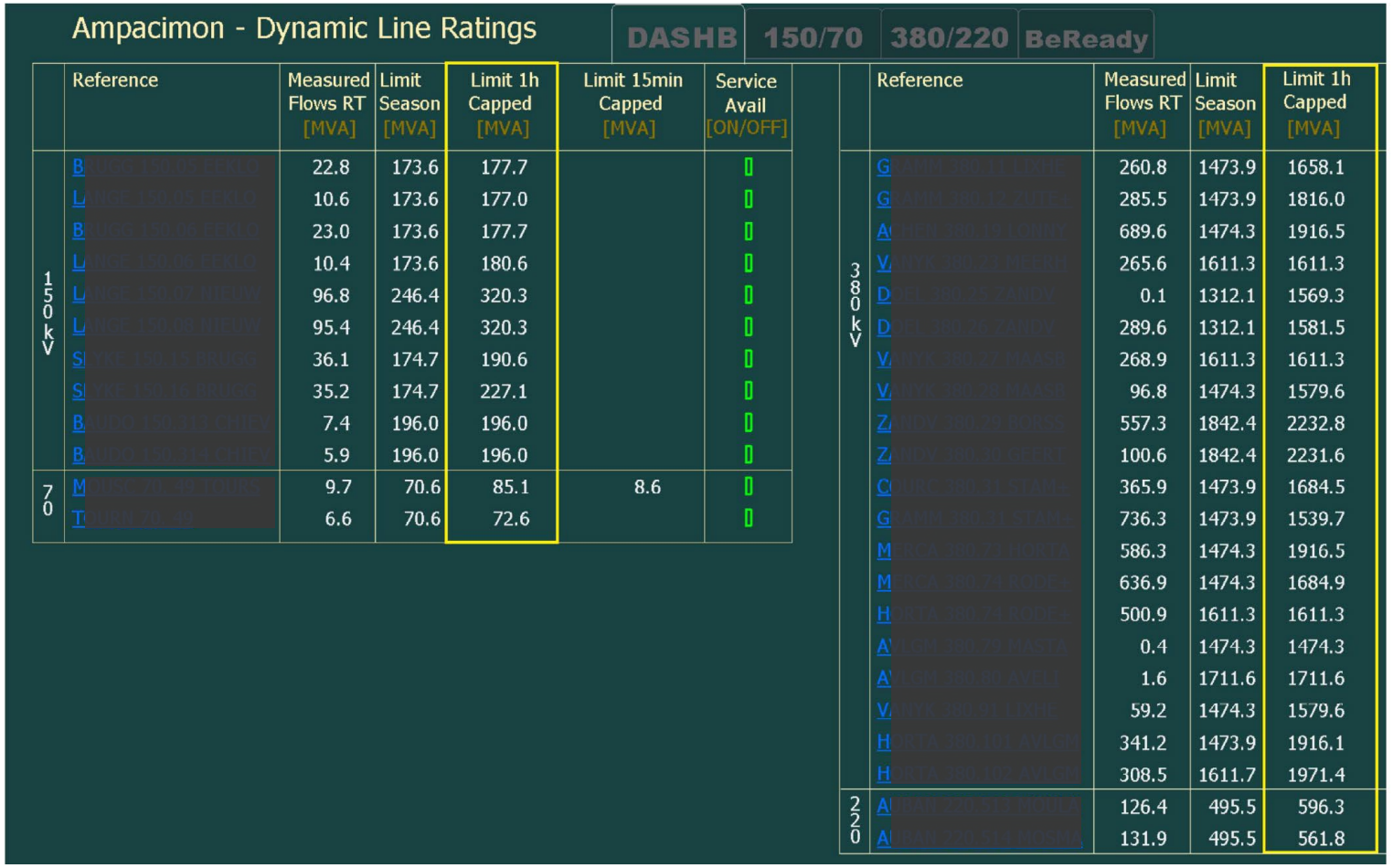
SCADA Integration (ABB)



Ampacimon - Dynamic Line Ratings

DASHB | 150/70 | 380/220 | BeReady

	Reference	Measured Flows RT [MVA]	Limit Season [MVA]	Limit 1h Capped [MVA]	Limit 15min Capped [MVA]	Service Avail [ON/OFF]
150kV	B[illegible]	22.8	173.6	177.7		
	L[illegible]	10.6	173.6	177.0		
	B[illegible]	23.0	173.6	177.7		
	L[illegible]	10.4	173.6	180.6		
	L[illegible]	96.8	246.4	320.3		
	L[illegible]	95.4	246.4	320.3		
	S[illegible]	36.1	174.7	190.6		
	S[illegible]	35.2	174.7	227.1		
	B[illegible]	7.4	196.0	196.0		
	B[illegible]	5.9	196.0	196.0		
70	M[illegible]	9.7	70.6	85.1	8.6	
	T[illegible]	6.6	70.6	72.6		

	Reference	Measured Flows RT [MVA]	Limit Season [MVA]	Limit 1h Capped [MVA]
380kV	G[illegible]	260.8	1473.9	1658.1
	G[illegible]	285.5	1473.9	1816.0
	A[illegible]	689.6	1474.3	1916.5
	V[illegible]	265.6	1611.3	1611.3
	D[illegible]	0.1	1312.1	1569.3
	D[illegible]	289.6	1312.1	1581.5
	V[illegible]	268.9	1611.3	1611.3
	V[illegible]	96.8	1474.3	1579.6
	Z[illegible]	557.3	1842.4	2232.8
	Z[illegible]	100.6	1842.4	2231.6
	C[illegible]	365.9	1473.9	1684.5
	G[illegible]	736.3	1473.9	1539.7
	M[illegible]	586.3	1474.3	1916.5
	M[illegible]	636.9	1474.3	1684.9
	H[illegible]	500.9	1611.3	1611.3
	A[illegible]	0.4	1474.3	1474.3
	A[illegible]	1.6	1711.6	1711.6
	V[illegible]	59.2	1474.3	1579.6
	H[illegible]	341.2	1473.9	1916.1
	H[illegible]	308.5	1611.7	1971.4
220	A[illegible]	126.4	495.5	596.3
	A[illegible]	131.9	495.5	561.8

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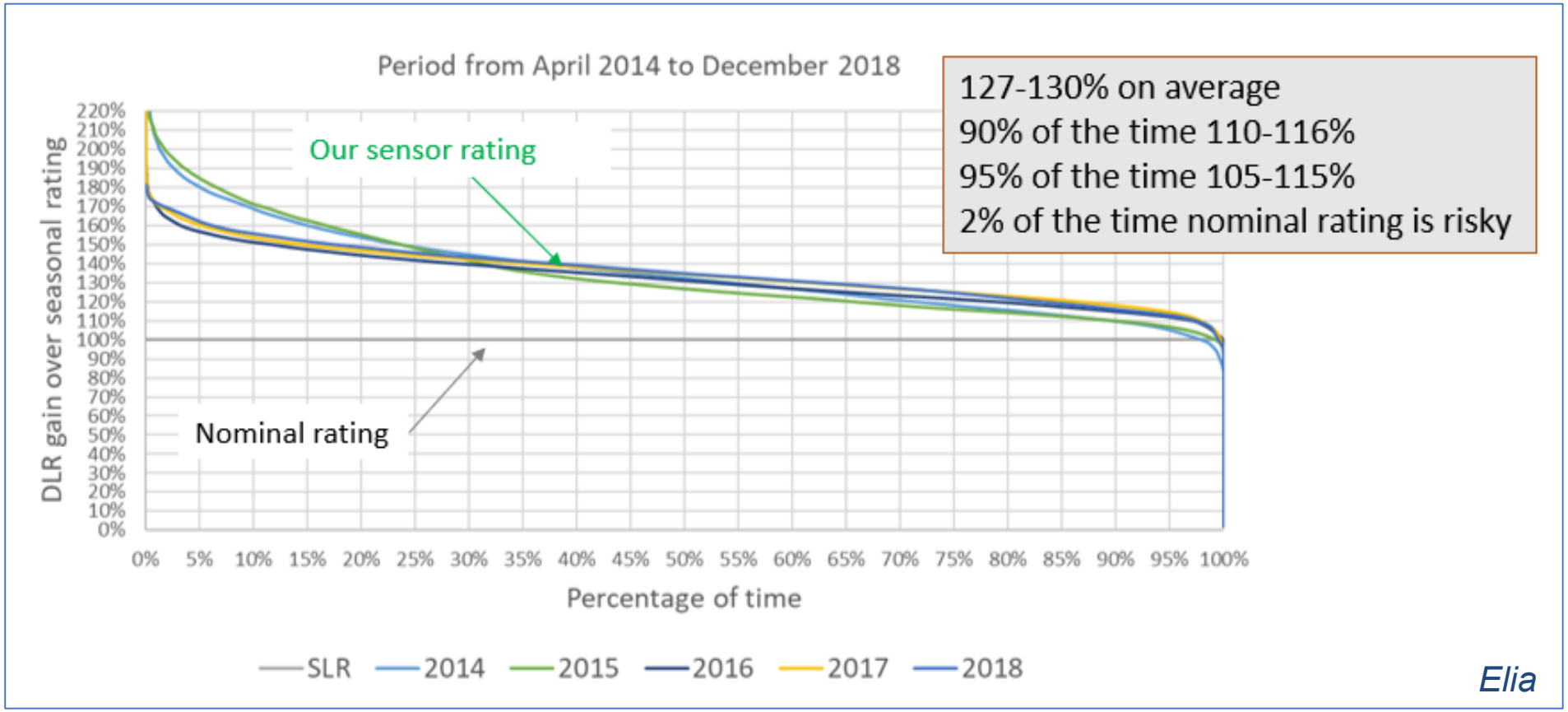
Elia DLR Results – 5 Years of Observation

DLR gains available 98% of the time



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Thank You

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