Cigre session 2024

Key-take aways from B2 - Overhead lines

For power system expertise

Preferential subjects 2024

PS1/Challenges from renewables integration and influences of energy transition on OHL

- Technical solutions for increasing power transfer capabilities of existing OHLs, methods for enhancing line/corridor utilization.

NL paper: Design challenges and recommendations in uprating the existing 380 kV Overhead lines

- Methods and strategies to accelerate approval and permit processes, stakeholder engagement.

NL Paper: Considerations for temporary earthing in compact and heavy loaded OHL

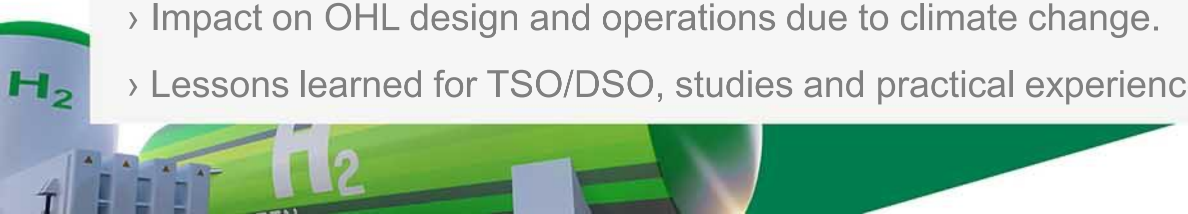
- Innovative solutions and construction techniques for overhead lines.

PS2/Asset management, strategies, technologies and methods for OHL

- Safeguarding of existing OHL from impacts of external infrastructure, encroachments, vandalism, sabotage.
- Asset health index (AHI), time-based and risk-based inspections, ageing, residual life assessments, protective treatment of components.
- Innovative maintenance methods, use of artificial intelligence (AI), augmented and virtual reality techniques (AR-VR) and increasing resilience.

PS3/ENVIRONMENTAL AND SAFETY ASPECTS FROM OHL

- Impact on OHL design and operations due to climate change.
- Lessons learned for TSO/DSO, studies and practical experiences from a changing environment.



NL Paper: Considerations for temporary earthing in compact and heavy loaded OHL (ID 10522)

Problem description

In the Netherlands we had the following trend in line design:

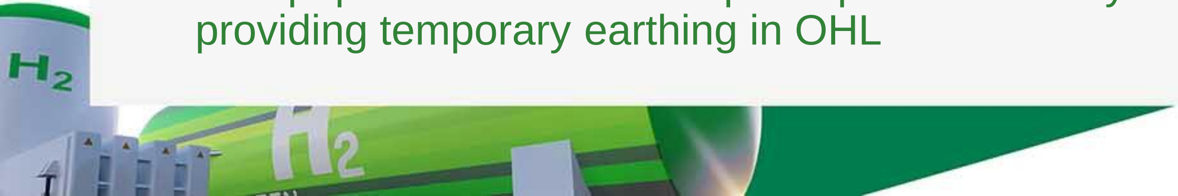
- Multiple circuits are combined on one tower (OHL)
- More optimization of tower configuration to limit the magnetic field width and lower the right of way
- Compact towers, smaller inter-phase and inter-circuit distances

Such designs have, however, disadvantages primarily due to the tight electromagnetic coupling between the circuits. In this regard the following concerns have been identified:

- 1) Personal safety: high induced voltages and currents in de-energized circuits may jeopardize safety of line workers
- 2) Protection: there is a risk of protection malfunction such as failure to operate or unwanted operation.
- 3) Earthing switches: induced currents and voltages in earthing switches in EHV and HV substations may exceed their capabilities (as defined in standards)
- 4) Voltage unbalance: grid code limits may be exceeded.

Focus of the paper

This paper addresses the topic of personal safety with focus on application of **Portable Earthing Devices (PED)** providing temporary earthing in OHL

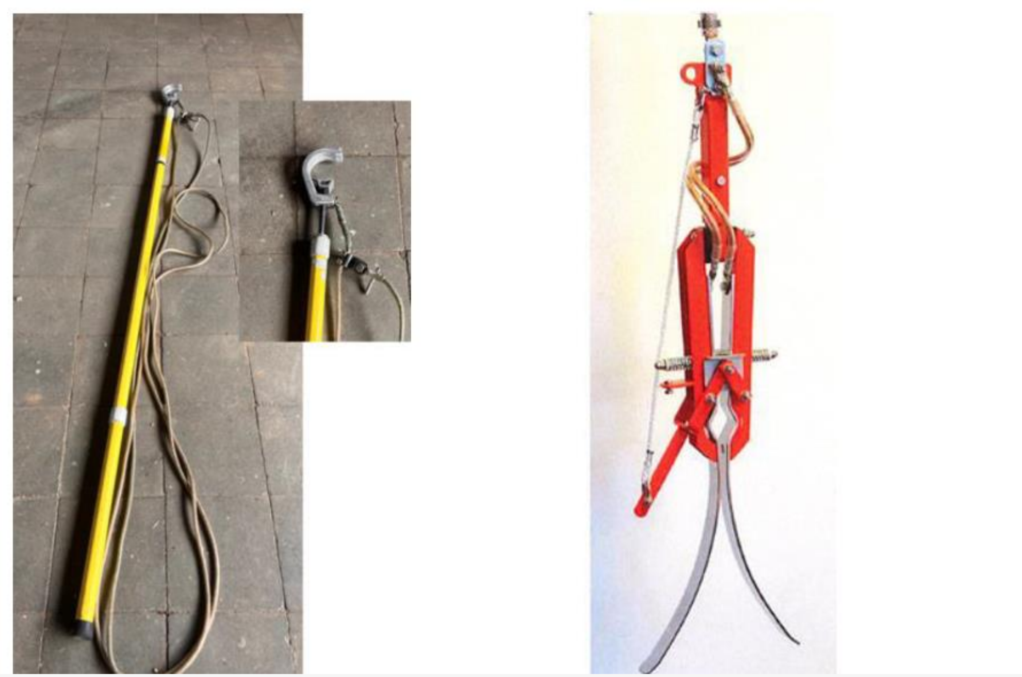


NL Paper: Considerations for temporary earthing in compact and heavy loaded OHL (ID 10522)

- Earth the OHL circuit at both ends by closing the line earth switches in the substations
- Verify the absence of voltage in the circuit of the tower where work will be performed
- Apply temporary earths in the work tower with portable earthing devices (PEDs)
- Apply “bracket” earths in the adjacent towers on both sides of the work tower.

Two typical PED used in the Netherlands:

- Left, the clamp type
- Right, the drop-on type



Simulations

Experience has shown that installed PED may get hot due to induced current and significant arcing may occur during (especially) removal or application of PED. In a few cases arcs of up to 0.5 meter have been reported. With this in mind, a PED current and PED voltage are defined:

- The “PED Current” is the induced current that will flow through the PED when it is connected between the phase conductor and the tower
- The “PED Voltage” is the voltage between the PED terminal and phase conductor just before it is connected, or just after it has been disconnected.

The magnitude of the PED current and PED voltage is influenced by factors such as:

- Presence of transpositions
- Tower configurations
- Tower position
- Induced currents and voltages

Simulations

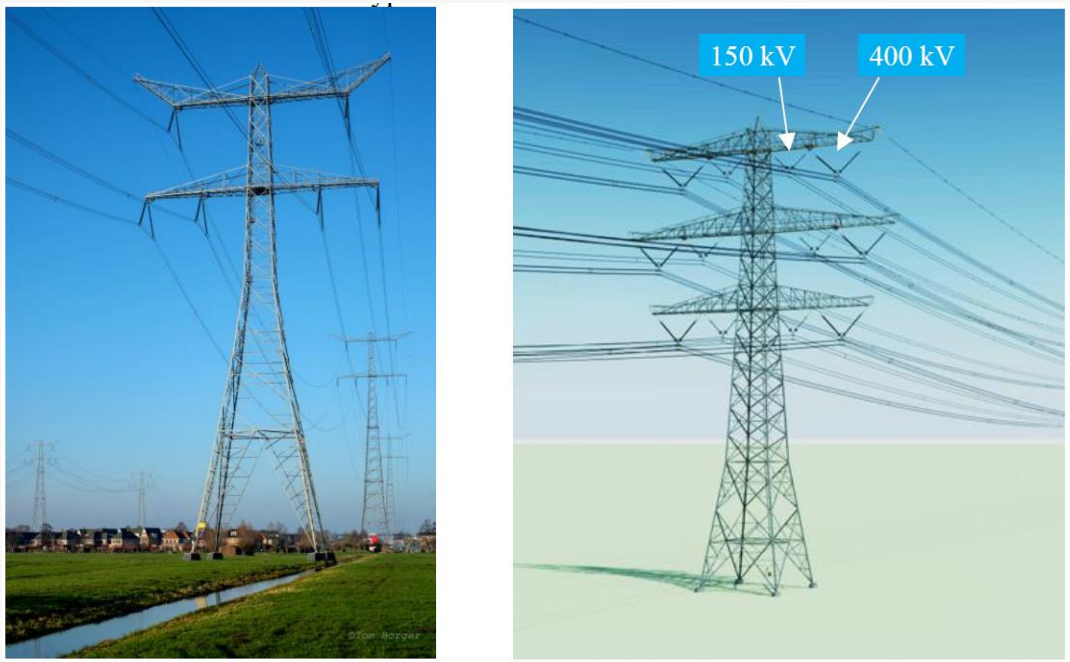


Figure 3 400kV Donau tower (left) and 2x400kV/2x150kV Moldau tower (right)

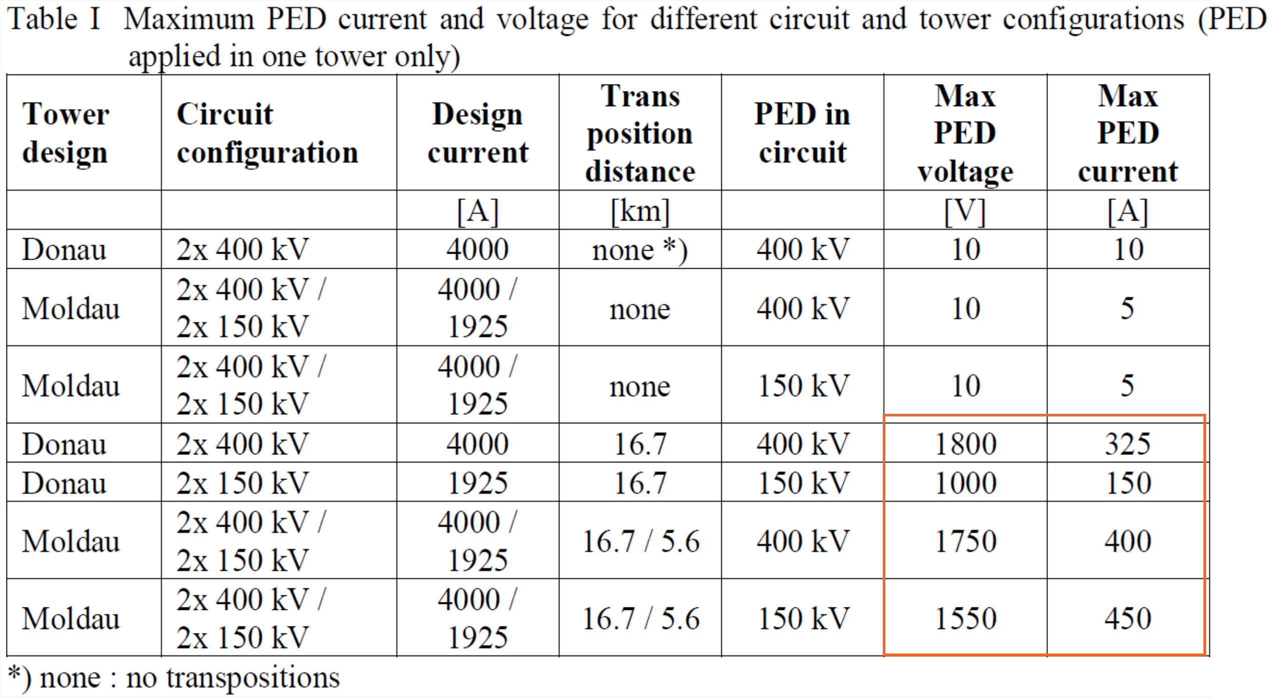


Table I Maximum PED current and voltage for different circuit and tower configurations (PED applied in one tower only)

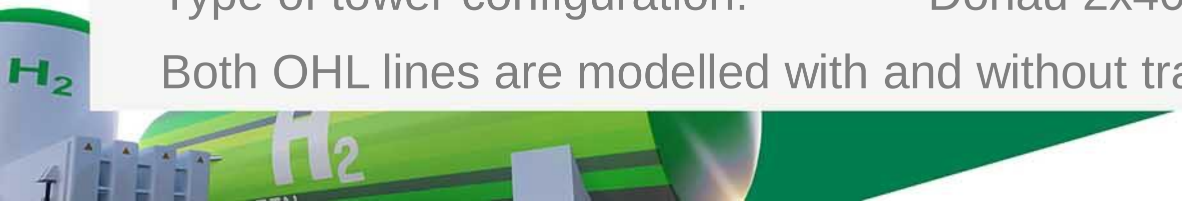
Tower design	Circuit configuration	Design current	Trans position distance	PED in circuit	Max PED voltage	Max PED current
		[A]	[km]		[V]	[A]
Donau	2x 400 kV	4000	none *)	400 kV	10	10
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	none	400 kV	10	5
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	none	150 kV	10	5
Donau	2x 400 kV	4000	16.7	400 kV	1800	325
Donau	2x 150 kV	1925	16.7	150 kV	1000	150
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	16.7 / 5.6	400 kV	1750	400
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	16.7 / 5.6	150 kV	1550	450

*) none : no transpositions

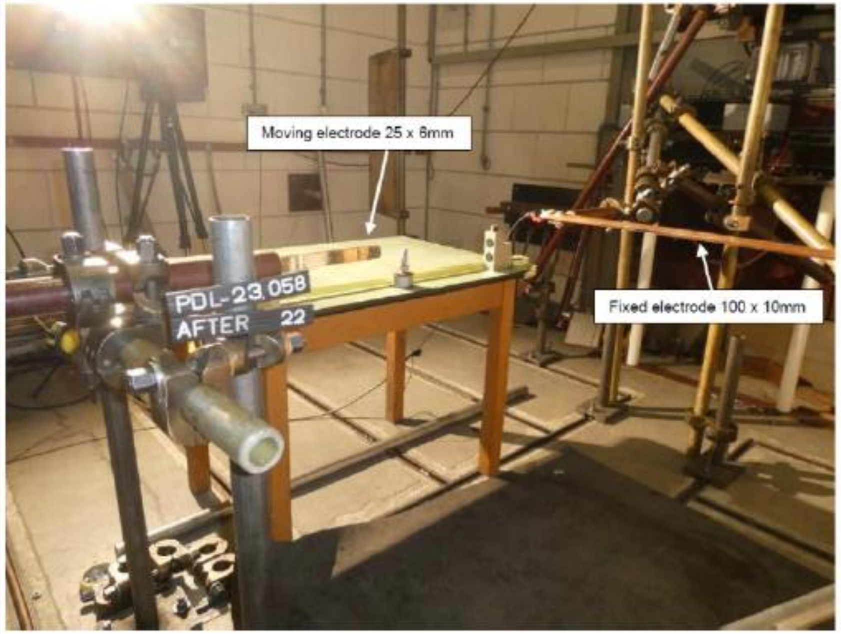
Assumptions:

Standard circuit length:	50 km
Type of tower configuration:	Donau 2x400kV, Moldau multi circuit 400kV / 150 kV

Both OHL lines are modelled with and without transposition



Tests and conclusions



Tower design	Circuit configuration	Design current	Trans position distance	PED in circuit	Max PED voltage	Max PED current	Arcing distance
		[A]	[km]		[V]	[A]	[m]
Donau	2x 400 kV	4000	none	400 kV	10	10	<0.01
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	none	400 kV	10	5	<0.01
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	none	150 kV	10	5	<0.01
Donau	2x 400 kV	4000	16.7	400 kV	1800	325	0.39
Donau	2x 150 kV	1925	16.7	150 kV	1000	150	0.20
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	16.7 / 5.6	400 kV	1750	400	0.42
Moldau	2x 400 kV / 2x 150 kV	4000 / 1925	16.7 / 5.6	150 kV	1550	450	0.42

Conclusions:

- in circuits without transpositions, the PED voltage and current are (very) low
- in circuits with transpositions and PEDs applied in a single tower, large currents (up to 500 A) may flow through the PEDs and large PED voltage (up to 2000 V) may occur.
- in circuits with transpositions and PEDs applied in three adjacent towers, the PED current may even increase (to more than 800 A). This increased current will occur in the two outer towers, the PED current in the work tower (middle tower) will be low, unless the work tower is a transposition tower.

NL paper: Design challenges and recommendations in uprating the existing 380 kV Overhead lines

- Beter benutten projects (BBB) project is to enhance the existing 380 kV grid

- Capacity increase is from 2,5 kA to 4 kA

- Special HTLS conductors are used to minimize tower and foundation reinforcements

This paper describes the design challenges and recommendations for upgrading the 380 kV OHL


Planning Beter Benutten Bestaande 380 kV

① 2019:
Uitvoering werkzaamheden Lelystad - Ens

② 2021-2022:
Uitvoering werkzaamheden Diemen - Lelystad

③ Zomer 2022:
Start uitvoering werkzaamheden
Krimpen - Geertruidenberg

④ Zomer 2023:
Start uitvoering werkzaamheden
Zwolle - Ens

⑤ Zomer 2023:
start uitvoering werkzaamheden
Rilland - Zandvliet

⑥ Zomer 2024:
Start uitvoering werkzaamheden
Maasbracht - Eindhoven

2026:
Uitvoering alle
werkzaamheden
gereed

Conductor selection for BBB projects

The ACCC (carbon fiber core conductor) is selected as the best fit for the reconductoring the exiting 380 kV grid

The main pro’s

- Reduced sagging of conductor (specially after knee-point)
- Good conductivity
- Low weight results in less stresses on the (tension) towers

The main con’s

- Installation needs more care (core is more fragile to bending
- More expensive compared to other HTLS conductor types

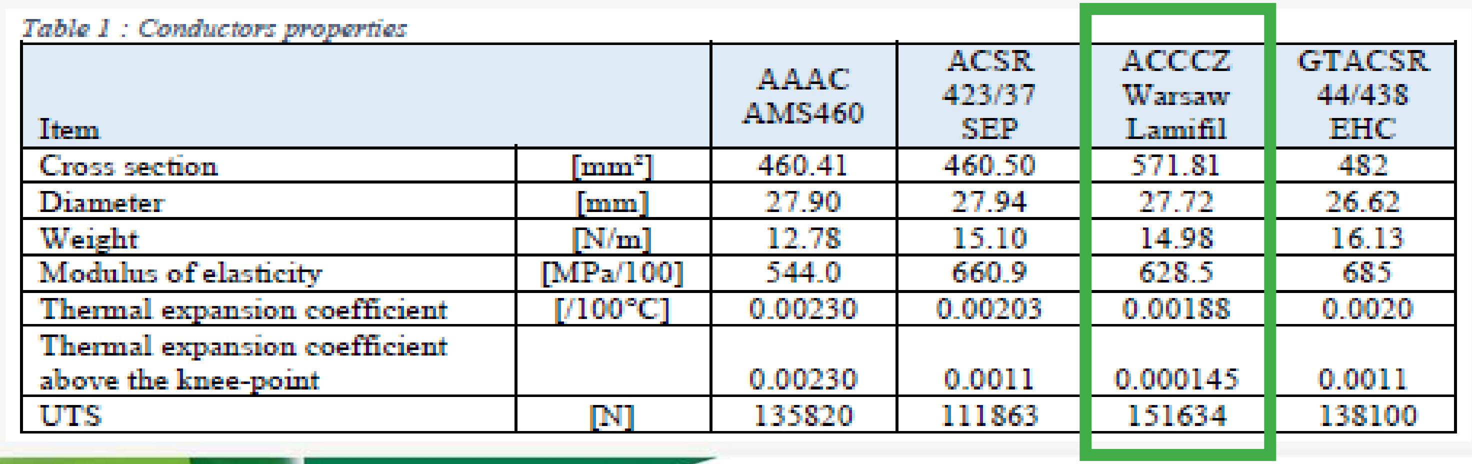


Table 1 : Conductors properties

Item		AAAC AMS460	ACSR 423/37 SEP	ACCCZ Warsaw Lamifil	GTACSR 44/438 EHC
Cross section	[mm^2]	460.41	460.50	571.81	482
Diameter	[mm]	27.90	27.94	27.72	26.62
Weight	[N/m]	12.78	15.10	14.98	16.13
Modulus of elasticity	[MPa/100]	544.0	660.9	628.5	685
Thermal expansion coefficient	[/100°C]	0.00230	0.00203	0.00188	0.0020
Thermal expansion coefficient above the knee-point		0.00230	0.0011	0.000145	0.0011
UTS	[N]	135820	111863	151634	138100

Challenges during installation

Pre-stressing the conductor

The conductor needs to be pre-stressed before clamped in the towers. A tension of 1,5x times the EDS tension is applied. The main reason is that the ACCC conductor has a very little creep effect and will only elongate when pre-stress is applied.

Induction due to energized other circuit

Heavy induction problems due to wrong earthing clamps and not enough earthing per line section

EMF aspects of the OHL upgrade

- Important aspect of the upgrade is limiting the 0,4 mT magnetic field width
- Phase optimization was used to lower the magnetic field.
- Even increasing the ampacity with 60% due to phase optimization the magnetic field size did not increase.

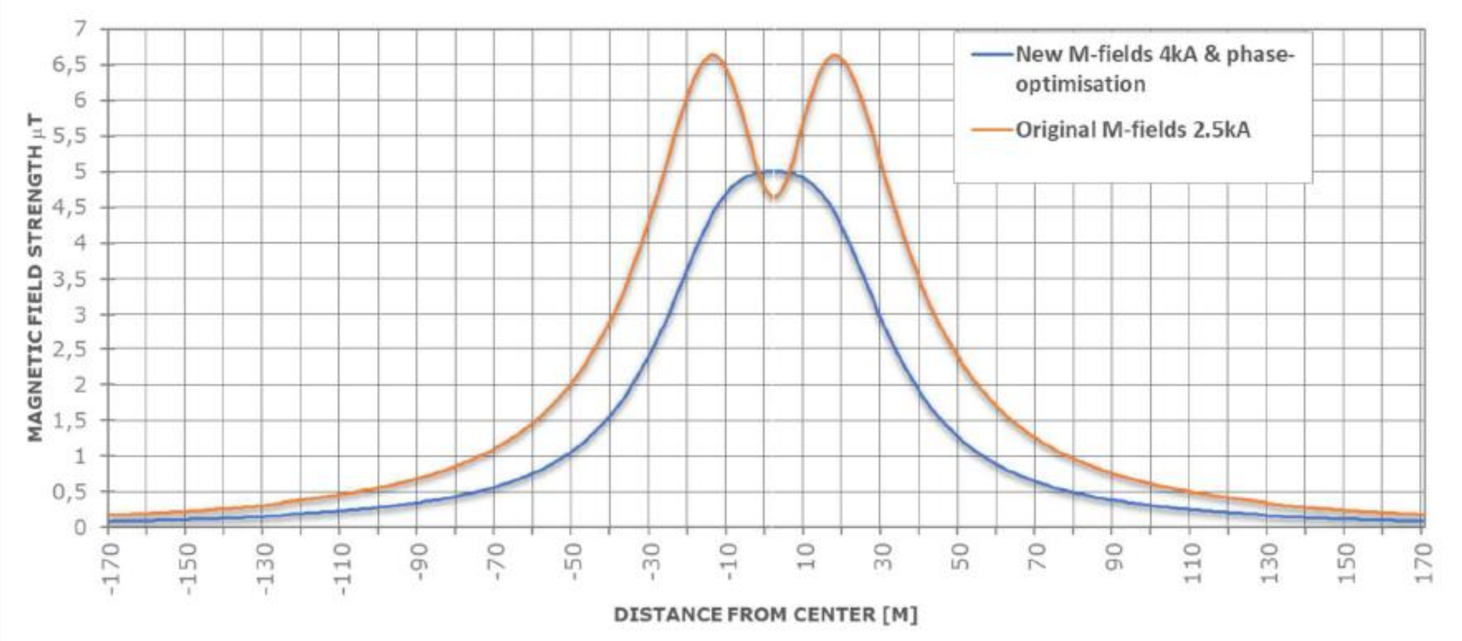


Figure 5 Magnetic field strength distribution across the line

Structural assessment upgrading

- Majority of the Dutch OHL are been built in the 60’ and 70’ based on the NEN 1060 standard. Increase loads on the tower change, the standard NEN 1060 is not applicable more and should be assessed on the Eurocodes.
- The Eurocode rules are much more stringent and would lead to many reinforcements.
- To bridge the gap – between the NEN 1060 and the NEN – EN 50341 – a study has been performed to find a suitable approach and still respects the Eurocodes
- Together with the research institute TNO and based on the NEN 8700 new set of load factors are been set up.

The new load levels resulted in a design load which is +/- 25% less compared to design load of new structure.

Line rating of overhead lines

Many articles contribute to the topic of current carrying capacity of overhead lines (line rating), most of them on Dynamic Line Rating (DLR).

For future prediction, weather forecasts are necessary. Sensors may have added benefit.

Although there seems to be consensus that combined approach leads to the best result, the discussion remains which approach shall be taken. This depends on the needs and risk aversity of the utility.

Weather forecasting is normally based on large weather model calculations. Machine learning methods are upcoming and lead to good results. In the future, more is expected on this.

Line rating of overhead lines

Some important KTA

- Hot spot determination: many spans can be a hotspot for some time of the year, depending on exact weather conditions. This shall be reviewed per overhead line.
- Paper from Statnett on this shows their method on how to determine the amount of sensors. In this case, they calculate that 6 sensors on the example line will provide an acceptable accuracy. More sensors will not contribute that much.
- Terrain layout is important aspect for DLR, since the local windspeed is the most dominant influence in the line rating. Local wind speed and angle can vary much.
- Measurement of solar radiation absorptivity is done by Hydro Quebec using a line robot and provides good insights.

Dielectric testing of Carbon core conductor (ID: 10136)

The HTLS carbon conductor we use in Netherlands is a (hybrid) core with annealed aluminium stranded around.

The build up is center core is a carbon fibre matrix, surrounded by glass fibre layer, and surrounded by stranded annealed aluminium

Carbon core is conducting, glass fibre layer is insulating and the stranded aluminium wires are are conducting

Figure 1: Conductor schematics from an electrical perspective

Dielectric testing of Carbon core conductor (ID: 10136)

If failure happens to the core a crack will propagate through the carbon and glass layer

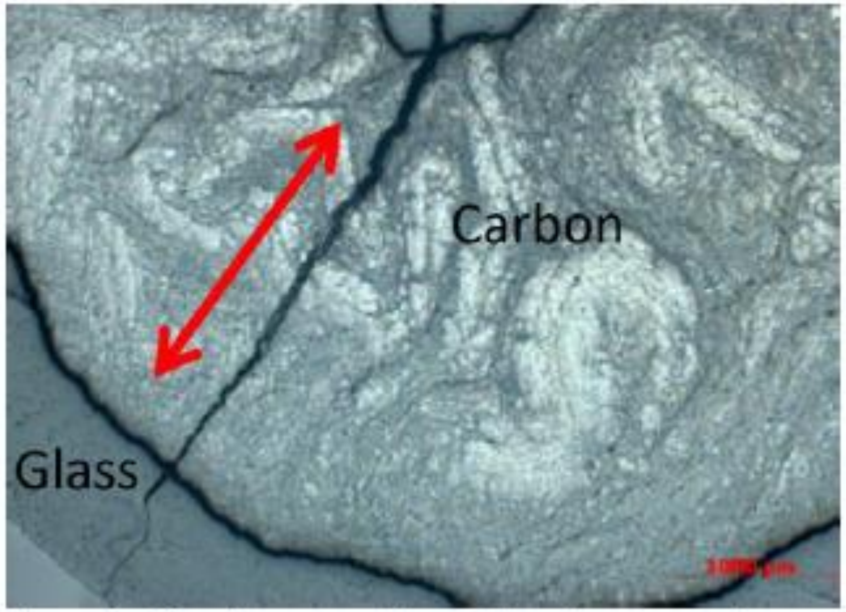


Figure 2: Crack propagation pattern in composite cores

Epsilon (carbon core supplier) has developed a dielectrical test to check the core integrity

Dielectric testing of Carbon core conductor (ID: 10136)

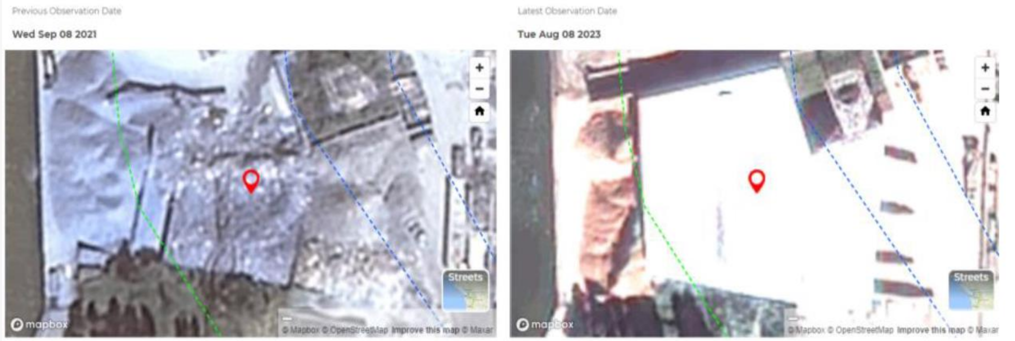
Testing can be done with a mobile dielectrically tester applying between 500V to 5kV to check the core

Figure 6: Conductor preparation and r

The test can be done during after stranding the conductor, after shipment, and in the tower before pressing the clamps on the conductor.

Satellite monitoring OHL (ID: 10705)

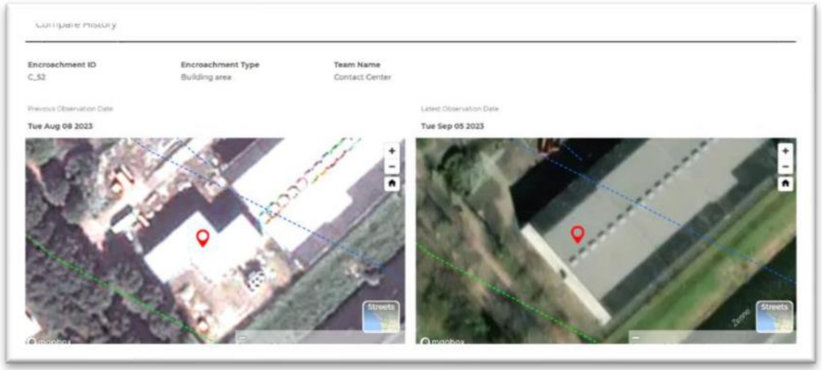
- Global land-use monitoring on OHL level can possibly be used to identify high-risk changes in area use.
- Remaining challenges:
  - Cost
  - Terrain
  - Interpretation of results
  - Implementation



Previous Observation Date
Wed Sep 08 2021

Latest Observation Date
Tue Aug 08 2023

Figure 9: Construction of a new industrial building



Compare History

Encroachment ID
C_52

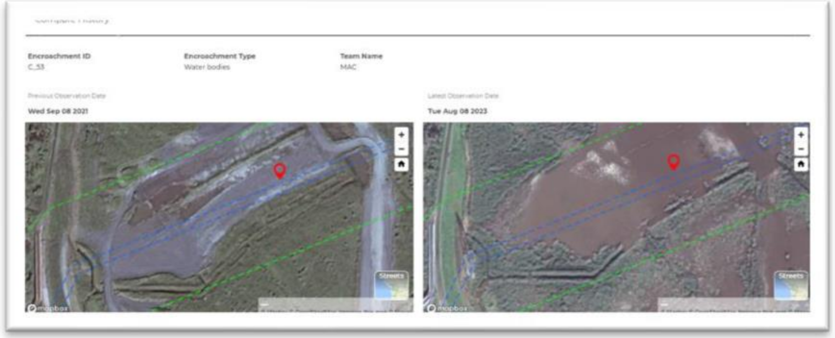
Encroachment Type
Building area

Team Name
Contact Center

Previous Observation Date
Tue Aug 08 2023

Latest Observation Date
Tue Sep 05 2023

Figure 6: Change in built area on OHL 5 identified with IEMS



Encroachment ID
C_53

Encroachment Type
Water bodies

Team Name
MAC

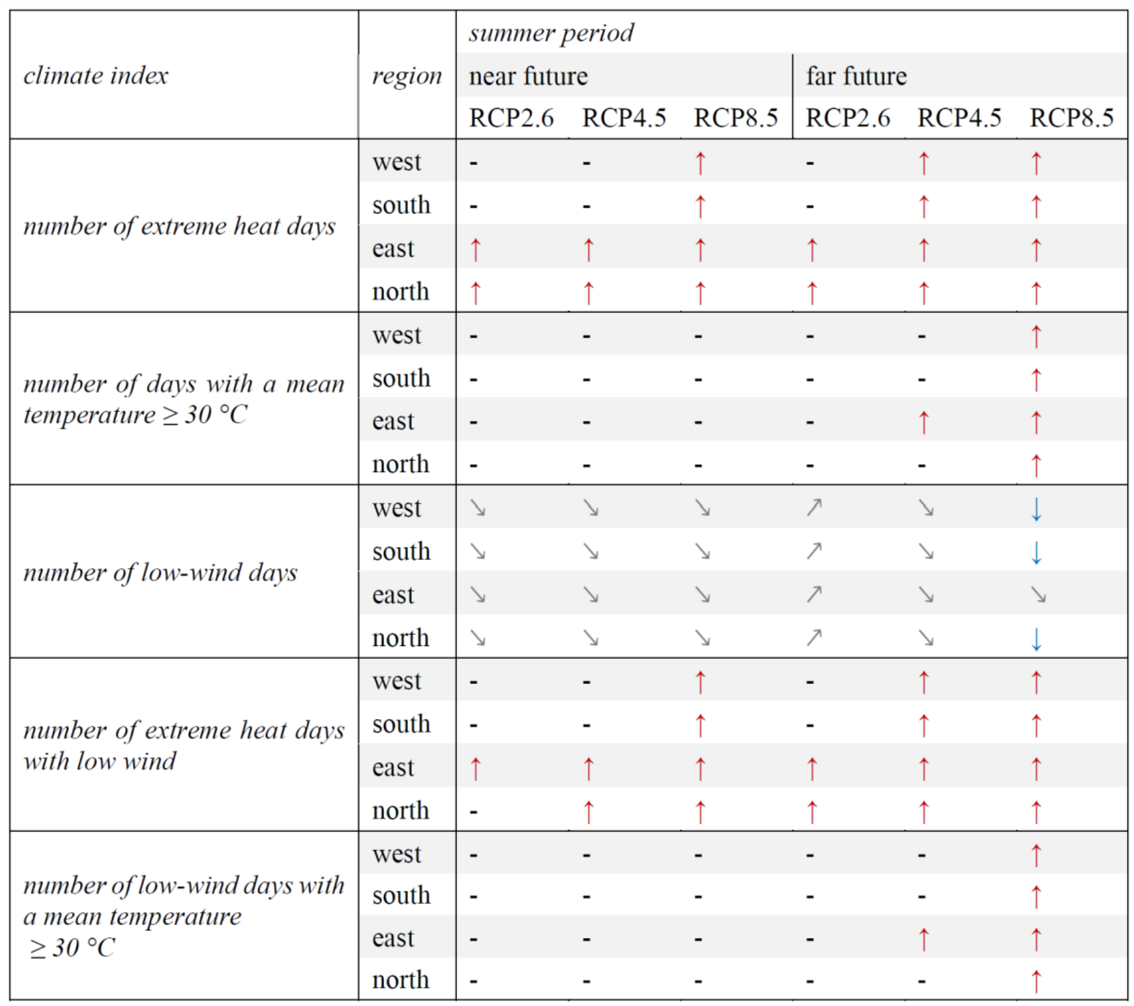
Previous Observation Date
Wed Sep 08 2021

Latest Observation Date
Tue Aug 08 2023

Figure 7: Flooded vegetation on OHL 5 identified with IEMS

PS3/ENVIRONMENTAL AND SAFETY ASPECTS FROM OHL

- Multiple papers regarding challenges in climate change, mostly focused on:
  - Ice and snow (incl. ice shedding)
  - Bush fires
  - Hurricanes / changes in wind load
- Investigation of future development of temperature an low wind velocity in climate change for the Austrian power grid (ID: 11158)
  - Analysis of the effects of climate change on the Austrian power grid:



climate index	*region*	*summer period*					
		near future			far future		
		RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
number of extreme heat days	west	-	-	↑	-	↑	↑
	south	-	-	↑	-	↑	↑
	east	↑	↑	↑	↑	↑	↑
	north	↑	↑	↑	↑	↑	↑
number of days with a mean temperature ≥ 30 °C	west	-	-	-	-	-	↑
	south	-	-	-	-	-	↑
	east	-	-	-	-	↑	↑
	north	-	-	-	-	-	↑
number of low-wind days	west	↘	↘	↘	↗	↘	↓
	south	↘	↘	↘	↗	↘	↓
	east	↘	↘	↘	↗	↘	↘
	north	↘	↘	↘	↗	↘	↓
number of extreme heat days with low wind	west	-	-	↑	-	↑	↑
	south	-	-	↑	-	↑	↑
	east	↑	↑	↑	↑	↑	↑
	north	-	↑	↑	↑	↑	↑
number of low-wind days with a mean temperature ≥ 30 °C	west	-	-	-	-	-	↑
	south	-	-	-	-	-	↑
	east	-	-	-	-	↑	↑
	north	-	-	-	-	-	↑