CIGRE e-Session 2020

For power system expertise

Key Take Aways

B2 – Overhead Lines

Andries van der Wal

andries.vanderwal@dnvgl.com

B2 – Overhead Lines

- Active Working Groups
- Tutorial
- Preferential Subjects 2020
- Papers 2020 Session
- Preferential Subjects 2022

Active Working Groups

- B2.40: “Calculation of electric distances between live parts and obstacles for OHL” TB in final draft
- B2.50: “Safe handling of fittings and conductors” (TB expected for India 2019)
- B2.57: “Survey of operational composite insulator experience and application guide for composite insulators” (TB and tutorial expected 2019)
- B2.58: “Vibration modeling of high temperature low sag conductors – Self damping characterisation (TB re-scheduled to 2019)
- B2.59: “Forecasting dynamic line ratings” (TB and Tutorial scheduled to 2019)
- B2.60: “Affordable overhead transmission lines for Sub-Saharan countries” (TB and Tutorial scheduled for 2019)
- B2.61: “Transmission line structures with fibre reinforced polymer (FRP) composites” (TB scheduled for 2019) paper in final stage Member: Erwin Platenkamp

Active Working Groups

- B2.62: “Design of compact HVDC OHL” (**Discussion regarding a book “compact lines”** by B2.62 & B2.63) (TB and Tutorial scheduled for 2019)

- B2.64: “Inspection and testing of equipment and training for live-line work on overhead lines” (TB and Tutorial scheduled for 2019)

- B2.65: “Detection, prevention and repair of sub-surface corrosion in OHL supports, anchors and foundations” (TB and Tutorial re-scheduled for 2021) **Convenor: Rob Meijers**

- B2.66: “Safe handling and installation guide for high temperature low sag (HTLS) conductors” (TB and Tutorial re-scheduled for 2020)

- B2.67: “Assessment and testing of wood and alternative material type poles “(TB and Tutorial re- scheduled for 2022)

- B2.68: “Sustainability of OHL, conductors and fittings – Conductor condition assessment and life extension ” (TB and Tutorial scheduled for 2021) Member Andries van der Wal

- B2.69: “Coatings for power network equipment” (TB and Tutorial re-scheduled for 2022)

Active Working Groups

- B2.70: “Aircraft warning markers and bird flight diverters for overhead lines – experience and recommendations” (TB and Tutorial scheduled for 2020)
- B2.71: “Recommendations for Interphase spacer for Overhead Lines” (TB and Tutorial scheduled for 2021)
- JWG B2/D2.72: “Condition Monitoring and remote sensing of overhead lines” (TB and Tutorial scheduled for 2022)
- B2.73: “Guide for prevention of vegetation fires caused by overhead line systems” (TB and Tutorial scheduled for 2022)
- B2.74: “Use of unmanned aerial vehicles (UAV´s) for assistance with inspections of overhead power lines” (TB and Tutorial scheduled for 2022) Member: Ranjan Bhuyan
- B2.75: “Application guide for insulated and un-insulated conductors used on medium and low voltage overhead lines” (TB and Tutorial scheduled for 2022)
- JWG B2/C4.76 “Lightning & Grounding Considerations for Overhead Line Rebuilding and Refurbishing Projects, AC and DC” (TB and Tutorial scheduled for xx)

Active Working Groups

- B2.77: “Risk Management of Overhead Line networks: A model for identification, evaluation & mitigation of operational risks” (TB and Tutorial scheduled for xx)
- B2.78: “Use of High Temperature conductors in new OH line design” (TB and Tutorial scheduled for 2024)
- B2.79: “Enhancing OHL Rating Prediction by Improving Weather Parameters Measurements“(TB and Tutorial scheduled for 2022)
- B2.80: “Numerical Simulation of electrical fields on AC and DC Overhead Line Insulator Strings” (TB and Tutorial scheduled for 2023) Member: Mohit Misra
- B2.81: “Increasing the Strength Capacity of Existing Overhead Transmission Line Structures” (TB and Tutorial scheduled for 2023)

Tutorial

WG B2.55 – TB 763

Conductors for the uprating of existing overhead lines

Physical modification, re-conductoring with conventional and high-temperature conductors

Topic of the study:

- Uprating methods
  - that require minimum outage time and cost
  - avoiding replacement or extensive reinforcement of existing structures.
- Conductor re-rating and conductor replacement with conventional and HTLS conductors
- Relatively short line (<150 km) up to 400 kV

Tutorial

Four methods studied:

1. Increase Tc_{max} (maximum allowable conductor temperature) for the existing conductor
2. Replace the existing conductors with larger single conductors
3. Add a second conductor to make a 2-conductor bundle
4. Re-conductor with equal diameter High-Temperature, Low-Sag (HTLS) conductors

Not studied:

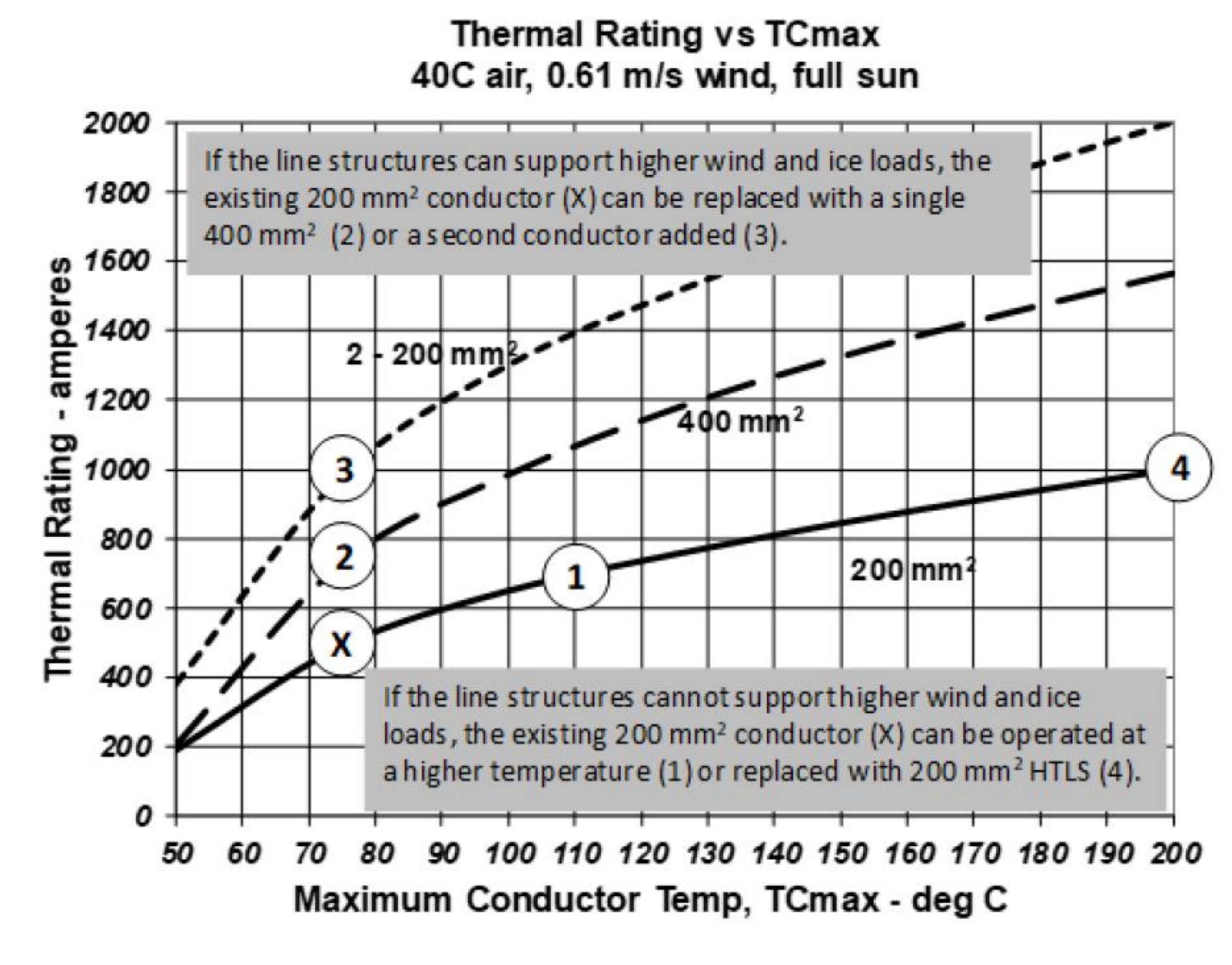
5. Probabilistic ratings
6. “Ambient-adjusted” ratings
7. “Dynamic” ratings

Tutorial

Graphical summary of 4 methods

- 200 mm² ACSR
- Rating 500 A
- Max temp 75°C

The TB contains a detailed technical analysis of the 4 methods but not an economic analysis



Preferential Subjects 2020

PS 1 / CONDITION BASED MAINTENANCE FOR INCREASED SUSTAINABILITY

- Monitoring and modelling
- Health index, remaining life, and degradation mechanisms
- Risk assessment

PS 2 / ENHANCING OVERHEAD LINE PERFORMANCE

- Innovative designs and materials; compaction; AC to DC conversion ; voltage upgrade; ampacity uprating; losses optimisation; etc
- Current carrying capacity
- Earthing, lightning performance

PS 3 / RESOURCES AND DESIGN CONSIDERATIONS

- Design with respect to construction; maintenance; lifetime and restoration; live line working; ergonomics; skills for installation and maintenance; robotics
- Design and refurbishment for a changing environment

Papers 2020

- PS 1: 18 papers
- PS 2: 23 papers
- PS 3: 10 papers

- Total 51 papers

B2-103: Development of sensors for real-time monitoring of ice loads on overhead lines
Norway

Norway is facing a lot of heavy snow problems problem on their overhead lines

The paper is about step by step phases of development of load sensors for real-time monitoring of OHL spans exposed to ice and snow

The ice load sensors together with meteorological data provide valuable input for an icing model, which will form the basis for a high resolution ice load map for whole Norway

Development of the load sensor

The prototype design specification is as follows:

- Nominal load 200 kN
- Safe overload 300 kN
- Ultimate over load 600 kN
- Protection class IP68
- Operating temperature -20°C / +50 °C
- Battery capacity: 1 year for the prototype, 10 years is the goal
- Resolution: 100 N
- Data transmitting: LTE, NB, CAT-M1

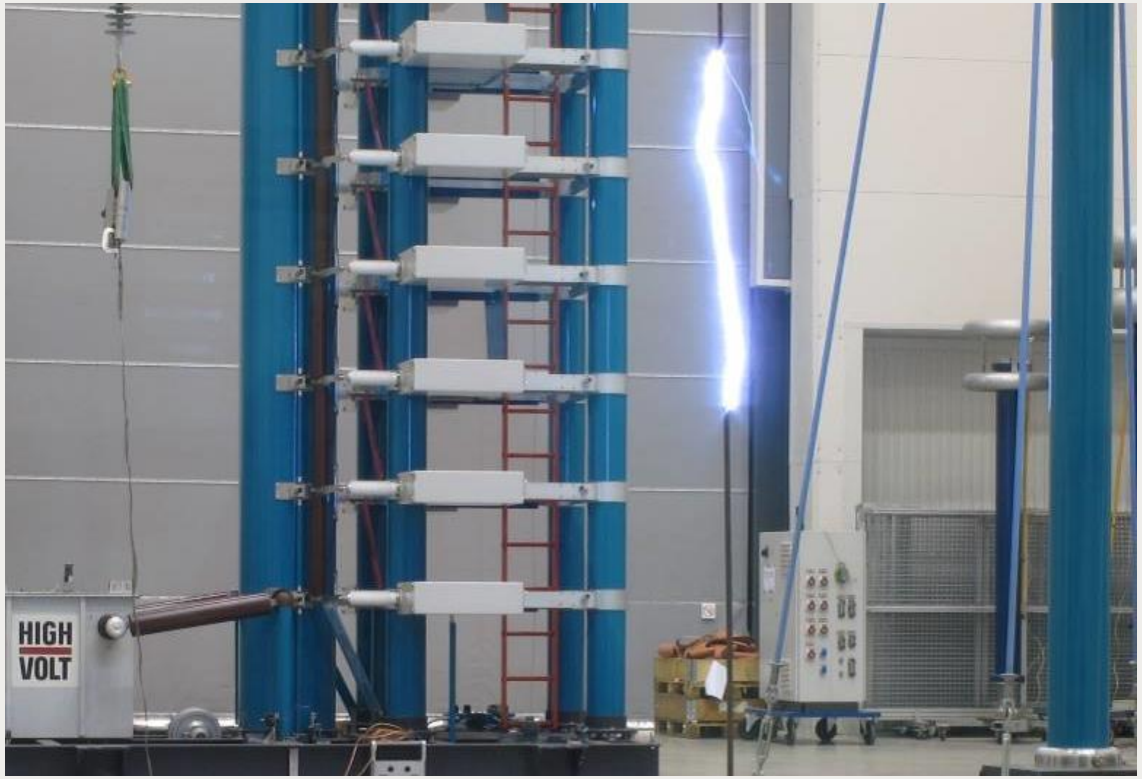
Verification of the sensor accuracy

Verification of the tensile strength

Verification of data transmitting in cold and wet conditions (buried in 0,5 meter of snow in all directions)

Interference test

- Influence of corona
- Influence of gap discharges induced by broken glass insulators
- Influence of nearby flashovers

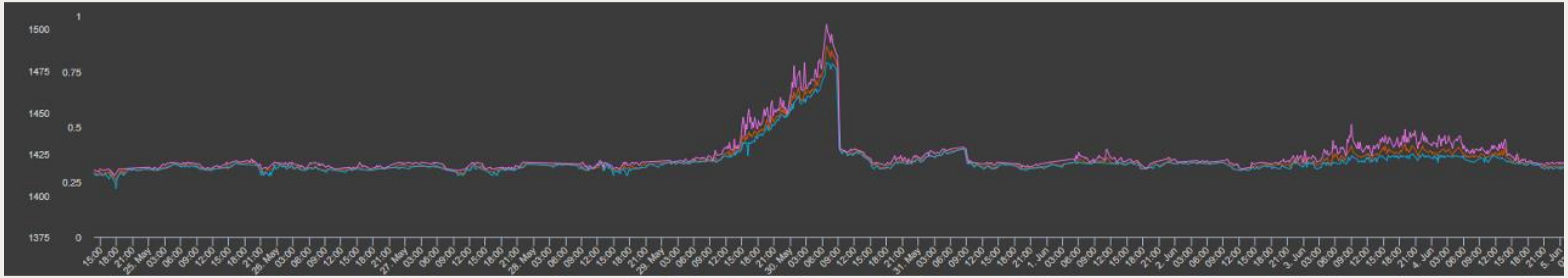


Testing of data transmission during nearby flashovers

All interference tests did influence the data transmission of the sensor but the level was considered acceptable

Implementation of ice sensor in the field

- In the beginning of 2020 they installed a sensor in one of the insulator string in a 420 kV tower
- They detected an ice load at 30th of May of around 0,9 kg / m



Note: 0,9 kg / m ice load is considered a minor ice loading. Ice loads up to 68 kg/m have been observed (In the Netherlands the max. ice loading is roughly 3 kg /m)

Next steps

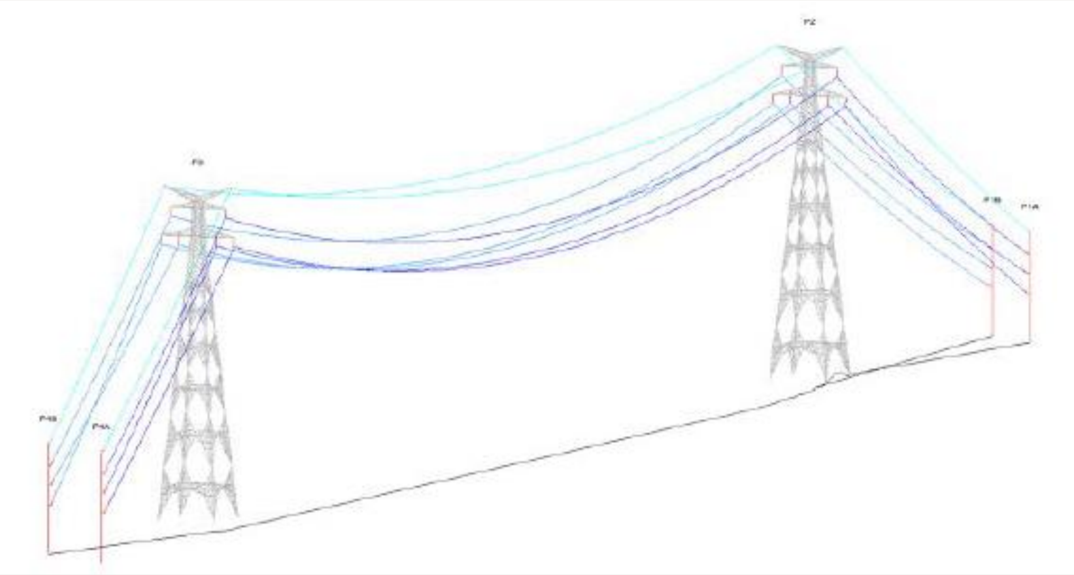
- Development of new sensor. It will be improved with respect to:

  - Operating temperature range (tested at -21 °C for 3 days)
  - Water tightness
  - Option for remote software updates
  - General software improvements
  - Increased battery lifetime (theoretically 10 years)
  - Stable data transfer using NB-IoT.

B2-203: Mega high strength steel core for HTLS conductor on 2nd Schelde long span crossing of new 380 kV OHL in the port of Antwerp Belgium

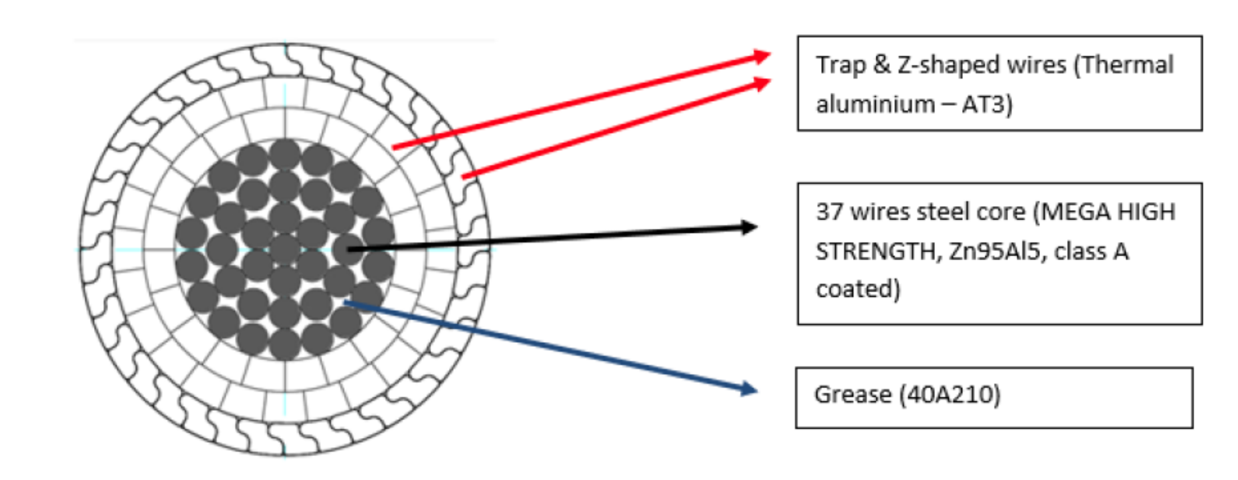
Design requirements

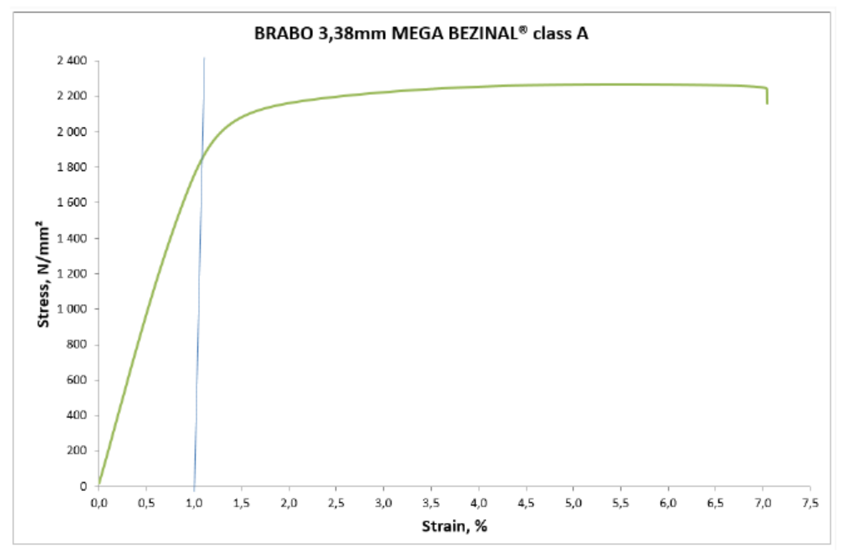
- Single conductor (less sensitive to galloping and requires no spacer dampers
- Closed conductor (Z-wires on the external layer) for better aerodynamical performance and mores corrosion resistance
- Permanent Ampacity 2766 A at 160 degrees
- High catenary of 3000 m
- Need of suitable diameter for audible noise limitation



Design of conductor

- Single conductor (44 mm diameter)
- Conductor could transmit 3450 A at its thermal limit of 210 degrees Celsius
- Special internal steel wires with coating (life expectancy 40 years)
    - Breaking tensile strength >2150 MPA
- Trapezoidal and Z-shaped outer wires





Challenges of installing the conductor

The installation of the phase conductors was a major challenge due to the difficulties of this project:

- specific procedure to install the pilot pulling ropes avoiding the interruption of the traffic by the river,
- pulley blocks placed at more than 166 m height,
- distance limitations to place the tensioner machine resulting in severe angles at the entrance of the conductor in the pulleys,
- necessity to respect a proper sequence of pulling to avoid excessive unbalance loads on the pylons,
- high pulling and regulation forces,
- installation of beacons/bird diverters and Stockbridge dampers all along the central span in extremely difficult conditions,..

Conclusion – lessons learnt

- These projects require a specific vibration study that can affect the installation methodology
- Special attention should be made to contractors regarding parts for installing the conductor
- Special installation manual should be developed in an early stage

By building the 2nd crossing Elia increases the security of supply of Belgium by enhancing the import capacity on the Northern border with the Netherlands

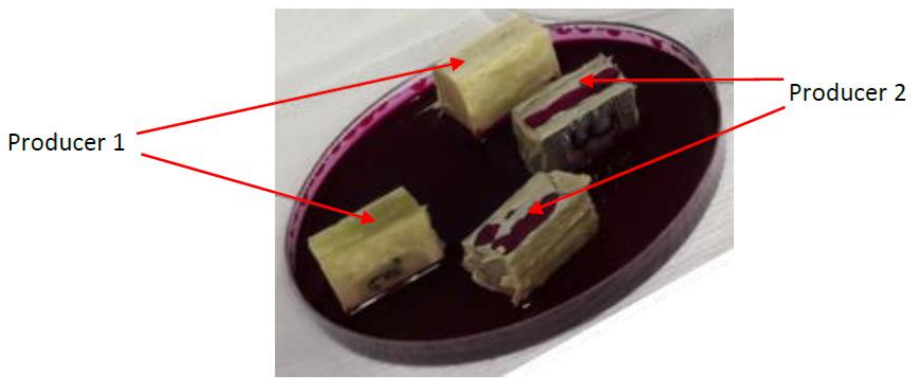
B2-204: Electric design and testing of composite towers for 420 kV Norway/the Netherlands

- Statnett is developing a 420 kV HV tower made out of Fibre reinforced Polymer (FRP)
- Attractive for Statnett because less helicopter use, reducing both the environmental impact and construction time while improving worker safety
- Lack of approved test methods for FRP material for High voltage towers for developing the electrical design
- Focus on material selection, insulation coordination, full-scale testing, electric field calculation and safety aspects

Material testing of FRP material from different suppliers

Table 2: Electrical and environmental test on composite samples.

Test	Type of test	Standard/refence
1	Thermal linear expansion	Standard practice. Informative test
2	Dye-penetration test	IEC 62217
3	Determination of electrical conductivity	ISO 14309
4	Determination of electrical breakdown voltage	IEC 60243-1
5	Dielectric strength	IEC 62217
6	Xenon-Arc weathering test	EN-ISO 4892/IEC 60068-2-14/IEC 62217
7	Tracking and erosion test	IEC 60587
8	Fire resistance test (glow wire/vertical flame)	EN 60695-2-10/IEC 60332-1-2

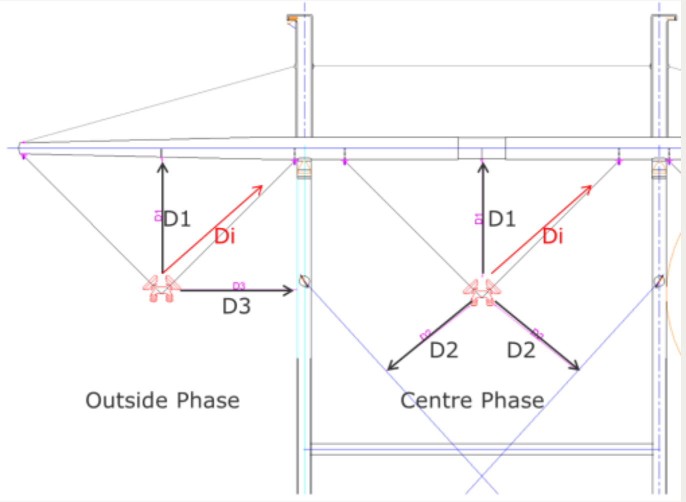


Dye-penetration test

The electrical and thermal behaviour of the material is important to know as input for the electrical design

Mock-up testing (able to adjust the internal clearances)

Defining the internal clearances
Note: Flashover to the structure is not allowed

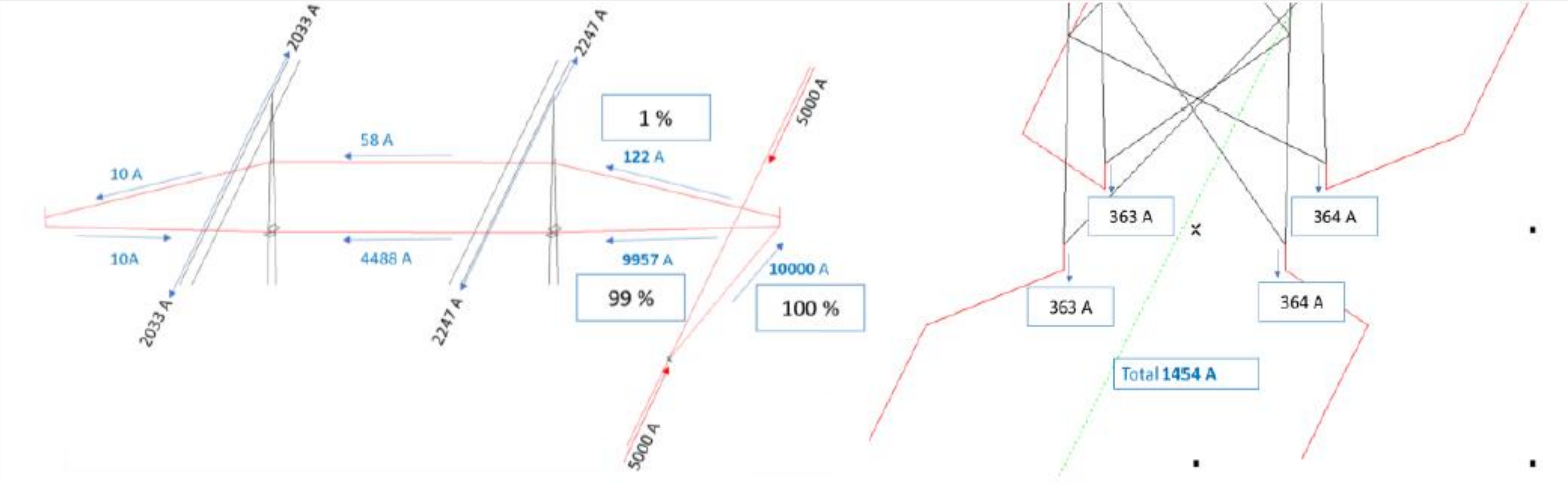


Lightning and switching impulse testing were performed to determine the minimum air clearances necessary to ensure flash-over will go over the string

Design of structure earthing

The earthing system is designed to ensure all faults and lightning currents are conducted safely to ground

CDEGS calculations were made to determine the currents and the necessary earthing along the structure



Conclusion

- Large difference between sample of different suppliers, regarding aging and leakage current

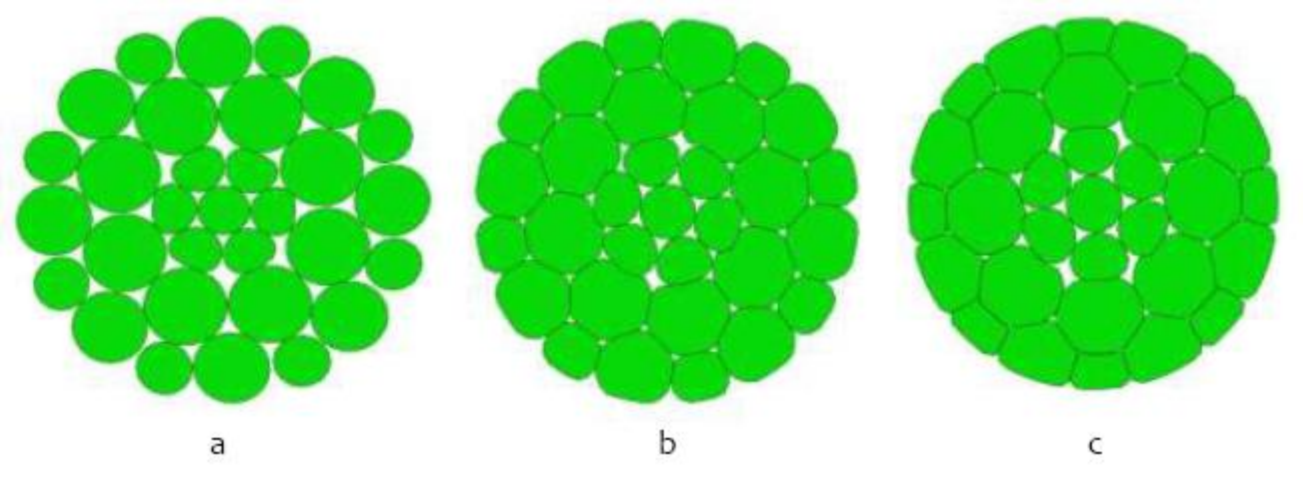
- Normally, one would seek to make composite structures as compact as possible, but this can be difficult to achieve as flashovers to the FRP pole should be avoided for the complete design life of the tower. This requires continuously optimizing the material selection and structure design. Close cooperation with all disciplines within the team

- When the design of the tower is finished it will be subjected to High-Voltage and High-Power tests to verify the electrical design and to make sure the structural integrity will be maintained

B2-220: Research of steel-aluminium plastically compacted conductors for overhead lines
Russia

High temperature / high strength aluminium and steel conductors will be permanent deformed in radial direction to strive to the following aspects

- More material in same diameter
- Allow for higher tension
- Better aerodynamical behaviour
- Lower cost than trapezoidal / z-shaped conductors



Conclusion

Based on test performed in two laboratories in Germany and simulations in Abaqus it was shown that the plastically compacted conductors reduce the load on the towers.

The conductors have the following technical advantages:

- Increase the wire fill factor to 92-97 % (compared to max, fill factor of ACSR to 78%)
- Reduction of aerodynamical load ~ 20 %
- Reduction of icing load ~ 25 %

B2-209: compactLine – Experiences with a pilot installation of an innovative overhead transmission line concept for 400kV Germany

compactLine was developed, constructed, tested and monitored in Germany

- Public acceptance
- 400 kV double circuit overhead line – 3600 A
- 2 km pilot line was constructed – 3 suspension and 2 tension towers

Monitoring program to detect potential defects and gather experiences during operation

Survey with residents done as well

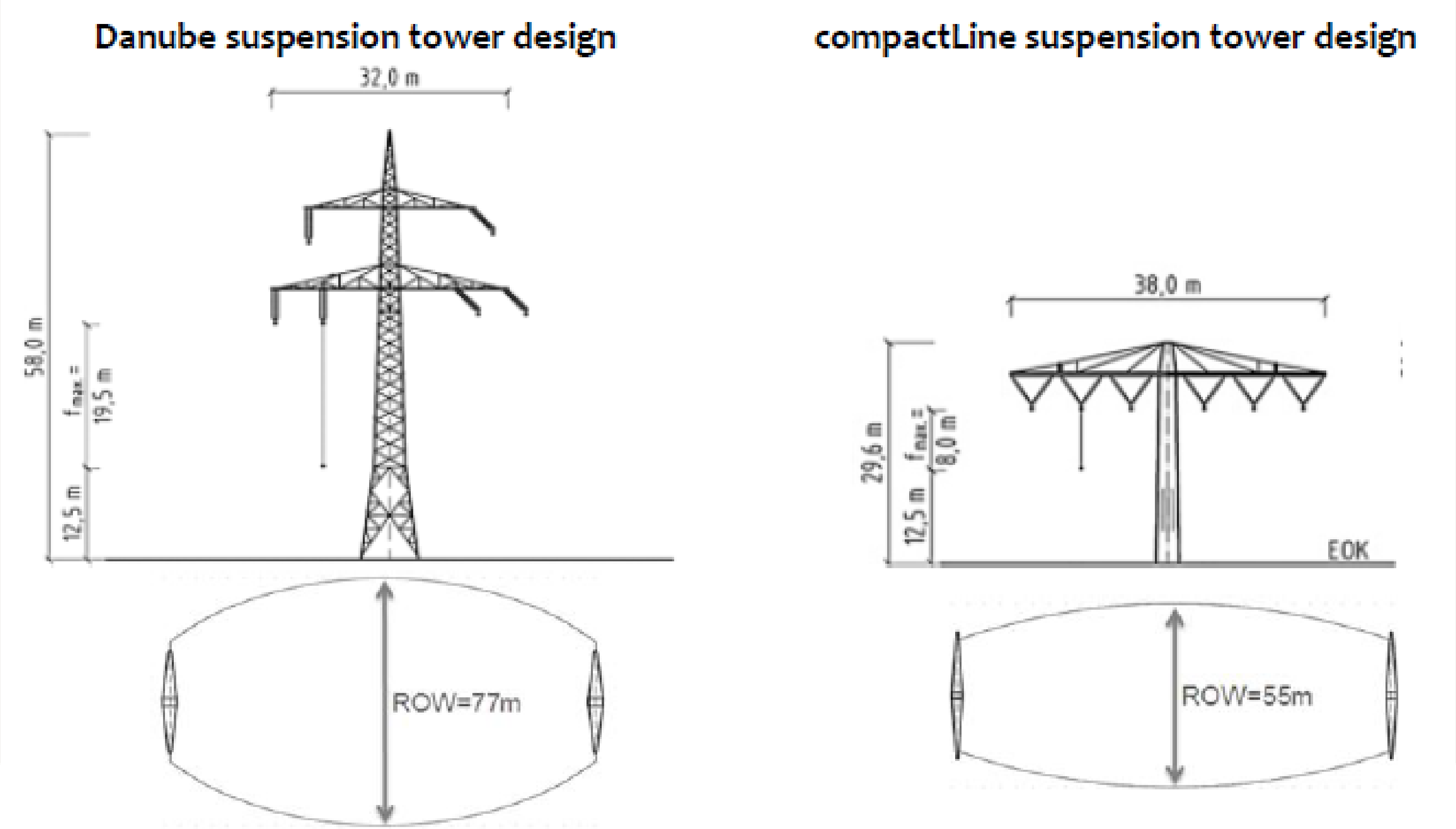
Drastically reduced sag by adding two steel ropes to the conductor bundle

Design

Tension forces 4 to 5 times higher than in conventional OHL

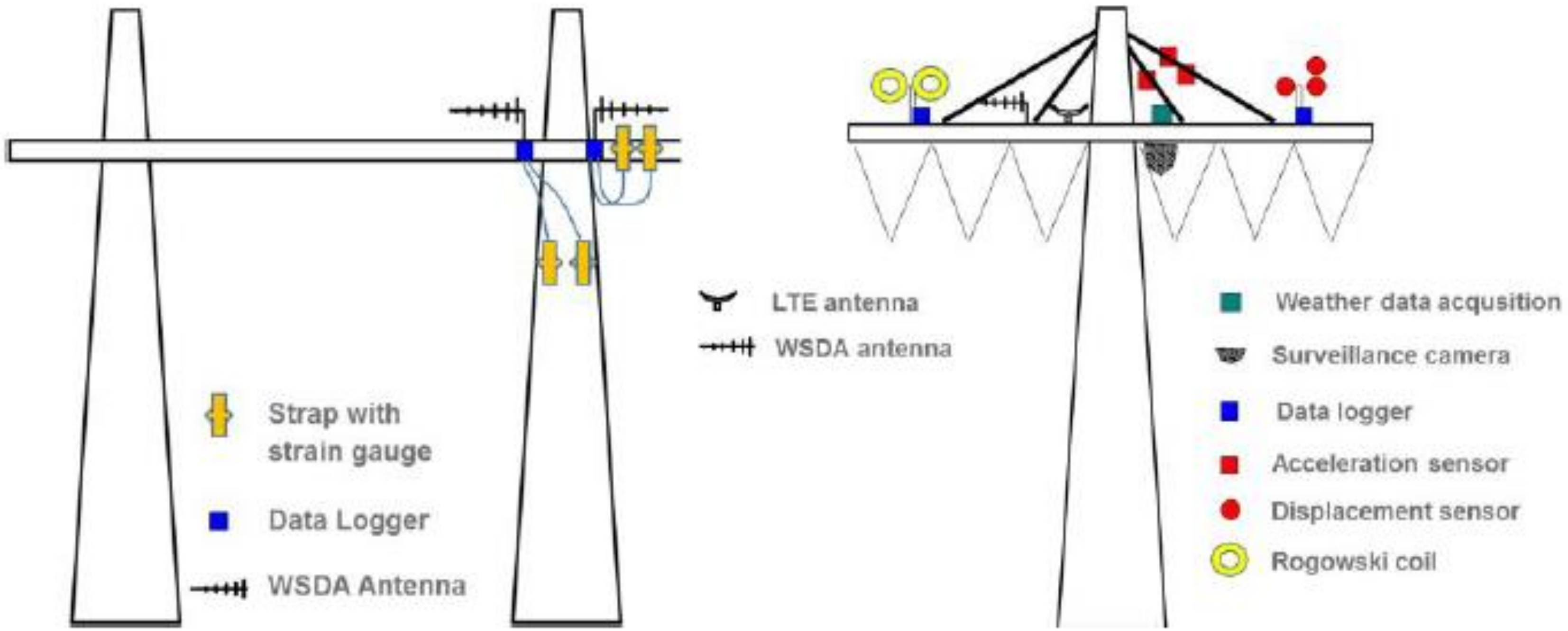
- New components required like bundle spacers and insulator sets
- Special installation methods

Extensive testing program was carried out, including full scale testing of conductor stringing



Monitoring and inspection program

Online Monitoring	Periodic inspection
Tension Tower	
Tension force in two bundles	Torque of bolts
Suspension tower	
Meteorological data	Torque of bolts
Vibration of tower tip and upper chords	
Vibration of ground wire	
Current in ground wire	
Spans	
Temperature of support steel rope	Sag
Movement of bundles (visual)	Visual inspection of tension clamps & bundle spacers (from line car)
Attenuation of OPGW	
Electromagnetic field emissions/ noise	

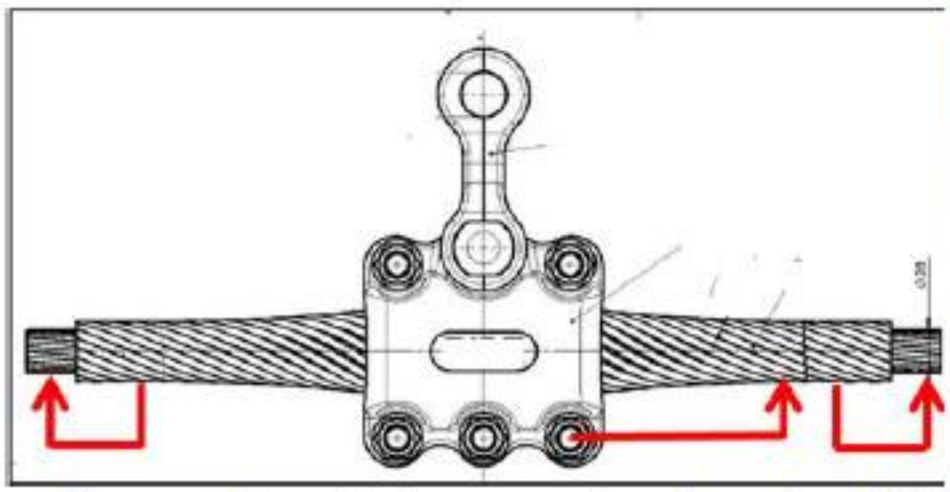


Tesion and suspension tower

Reduced sag of compactLine

Monitoring - examples

Stockbridge dampers applied in ground wire to reduce vibrations



Strain gauge at tension insulators

Acceptance of design

Research carried out by university

- Before installation
  - 40% preferred compactLine
  - 7% preferred Danube design
  - Rest indifferent
- After pilot installation
  - 50% preferred compactLine
  - 15% preferred Danube design
  - Rest indifferent

B2-212: Conception, Construction and Realisation of an innovative OHL Design
Germany/Denmark

Tower design based on tubular towers instead of lattice towers

- Gain operational experience with such structures
- Determine whether this design can increase public acceptance

New solutions required for technical design, logistics, assembly and operation

Audible noise and electromagnetic fields – within legal limits

Cost – higher than conventional towers

Tower design

PS 2022 (preliminary), STUDY COMMITTEE B2

PS 1 Challenges & New Solutions in Design and Construction of new OHL

- Design for reliability, availability, future climate parameters, more frequent extreme loads, design against theft, vandalism, terrorism
- AC/DC Hybrid Lines, multi-purpose utilization (e.g. renewables, telecommunication)
- OHL challenging construction projects: multiple circuits lines, high towers, long spans, heavy wind and ice, high altitudes, geology, access to site, no proper machinery, long lines and variation in reliability criteria etc.

PS 2 Latest Techniques in Asset Management, Capacity Enhancement, Refurbishment

- Preparedness and countermeasures for natural disasters and other emergencies
- Decisions of replacement based on monitoring, maintenance, operation, historical data
- Strengthening of existing lines to improve reliability, ampacity, lifespan

PS 3 Environmental and safety aspects from OHL (joint PS with C3?)

- Safety of workers in construction and maintenance of lines (equipment, methods, etc.)
- Reducing environmental impacts from new and existing OHL – for B2 and C3
- For C3

For power system expertise

andries.vanderwal@dnvgl.com

+31 6 1506 3571