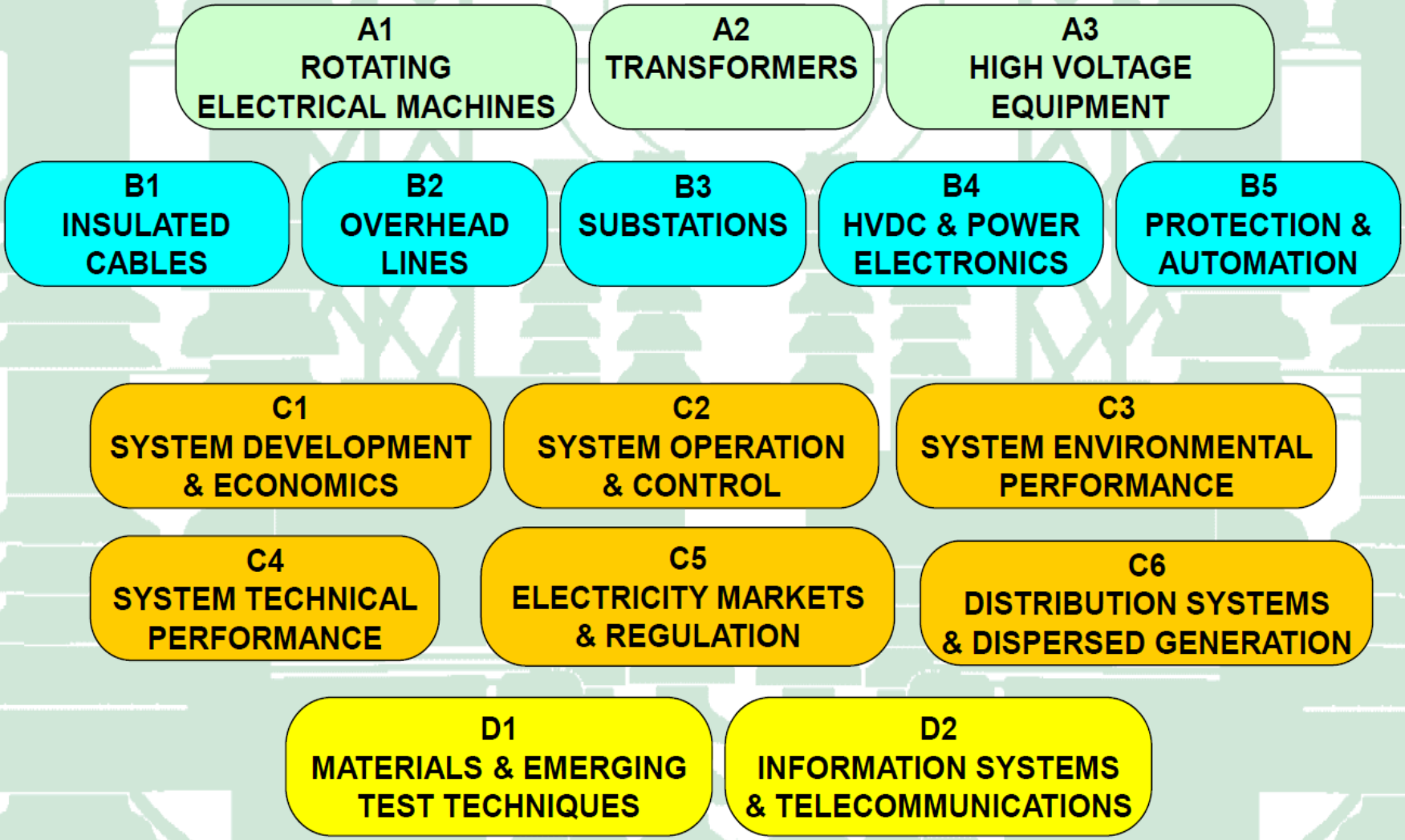
11TH INTERNATIONAL EXHIBITION OF ELECTRICAL AND INDUSTRIAL ELECTRONICS INDUSTRY
ELECRAMA-2014
8-12 JANUARY 2014, BIEC, BANGALORE, INDIA

Study Committee B2
"Overhead Lines"

Herbert Lugschitz, Secretary of B2
Austrian Power Grid (APG), Vienna

CIGRE's Study Committee structure



The increasing demand of energy leads to an increasing demand from lines.

The big majority of those lines (high voltage and extra high voltages) will be overhead.

This concerns the replacements of existing lines, building new ones, and uprated lines.

This is within the scope of B2

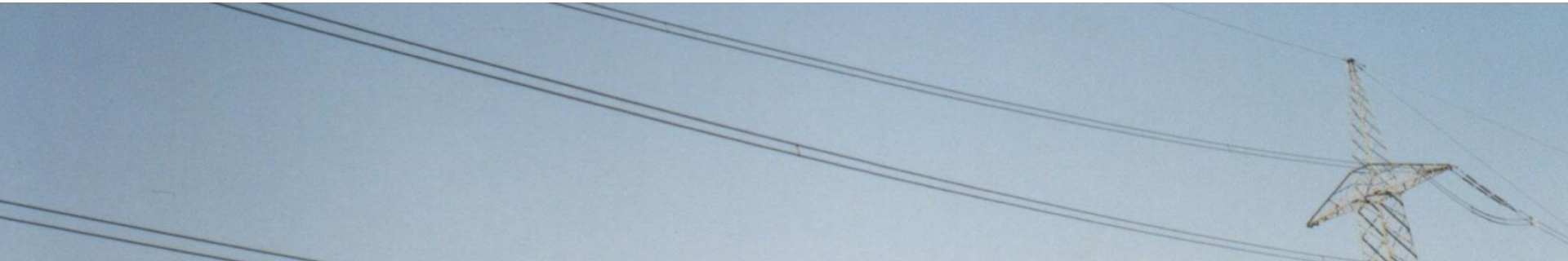
In many countries: OHL /UGC question – to be solved on a case by case basis

Cigre Study Committee B2

SC B2 covers all fields of overhead lines activities, which is the

- **design**
- **construction**
- **operation** of overhead lines
- including the **mechanical and electrical aspects**
- and the design of **line components**
  - conductors and ground wires
  - insulators
  - accessories
  - structures
  - foundations
  - validation tests

partially in cooperation with other study committees



Cigre Study Committee B2

It also covers the

- study of in **service performance**
- assessment of the **state of line components**
- **maintenance**
- **refurbishment**
- **upgrading** and **uprating** of overhead lines.

SCB2 Scopes

- Increase Acceptability of OHL
- Increase Capacities of existing OHL
- Increase Reliability and Availability of OHL

To cover this SC B2 is composed of

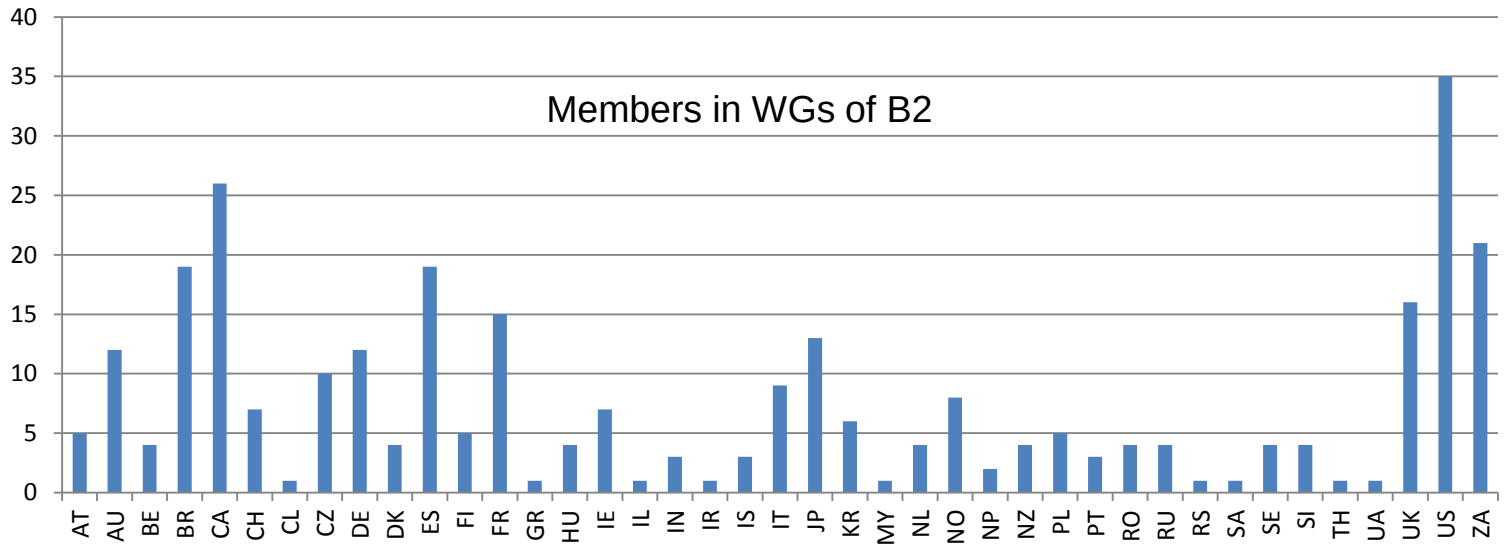
- **24 Working Groups**
- **two joint working groups** (Live line maintenance B2/B3 and Environmental issues for rural and urban areas C3/B1/B2)
- **7 Advisory Groups** help to coordinate.

Structure of SC B2

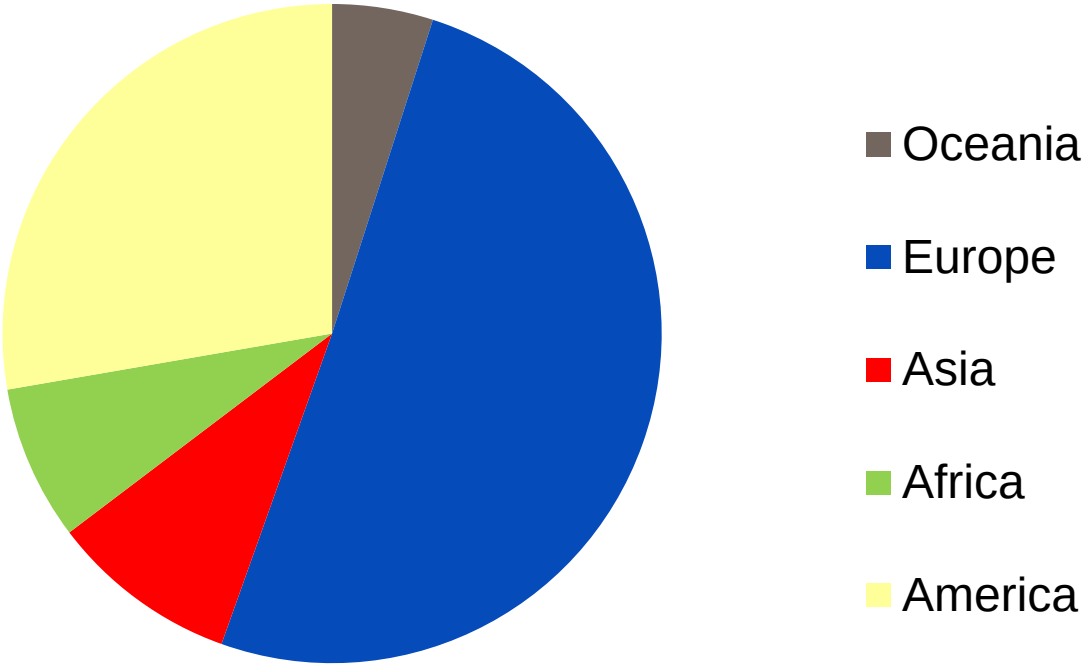
- **Members from 24 countries**

  Switzerland, Slovenia, Sweden, Brazil, United States of America, Ireland, Spain, Belgium, Norway, Canada, Russia, Australia, Finland, China, Austria, South Africa, Britain, South Korea, France, Germany, Italy, Czech and Slovak Republics, Japan, Poland

- Plus **Observers** (Iceland, Venezuela, India, Mexico, Portugal, the Netherlands, Romunia, Israel, New Zealand)
- **Chairman**: Konstantin Papailliou/CH, **Secretary**: Herbert Lugschitz/AUT
- **24 WG** with **311 members** from 41 different countries



WG members by continents



Cigré SC-B2 WGs

Working Group	
WG B2.21	Arc protection and diagnosis for **composite string insulators**
WG B2.23	Geotechnical and structural design of the **foundations** of HV & UHV Lines, application to the updating to the refurbishment and upgrading guide
WG B2.24	Qualification of HV and UHV Overhead **Line Supports under static and dynamic Loads**
WG B2.25	Preparatory studies on specifications for **revision of IEC** testing of Self Damping and conductor fatigue characteristics (new IEC Spec.)
WG B2.28	**Meteorological data** for assessing climatic loads. Update of IEC TR 61774
WG B2.38	Evaluation of High Surge Impedance Load solutions for **increased natural capacity** of OHL
WG B2.40	Calculations of the **electrical distances** between live parts and obstacles for OHL : Preparatory studies for revision of IEC standard (IEC61…
WG B2.41	Guide to the **conversion of existing AC lines to DC operation**
WG B2.42	Guide to Operation of Conventional **Conductor Systems above 100°C**
WG B2.43	Guide for **Thermal Rating Calculations** for Overhead Lines with high temperatures and real-time weather & load data
WG B2.44	**Coatings** for protecting overhead power network equipment **in winter conditions**
WG B2.45	**Bushfire** characteristics and potential impacts on Overhead Line Performance

Cigré SC-B2 WGs

Working Group	
WG B2.46	**Wind induced motion** on bundle conductors (excluding ice galloping)
WG B2.47	Remedial actions for **aged fittings and repair of conductors**
WG B2.48	Experience with the mechanical performance of **new conductor types**
WG B2.49	Safe design tension for **conductors fitted with elastomer cushioned suspension units**
WG B2.50	S**afe handling of fittings and conductors**
WG B2.51	Methods for **optimized design** of overhead transmission lines
WG B2.52	The use of **robotic** in assessment and maintenance of OHL
WG B2.53	Management guidelines for **outsourcing OHTL technical expertise**
WG B2.54	Management of risk associated with **severe climatic events and climatic change** on OHL
WG B2.55	Conductors for the **Uprating of existing Overhead Lines**
WG B2.56	**Ground Potential Rise** at Overhead AC Transmission Line Structures during Faults
JWG B2./B3.27	**Live line maintenance** : a management perspective
JWG C3/B2/B1.13	**Environmental issues** of high voltage transmission lines for rural and urban areas

Content of presentation

Current activities of B2 (excerpt)

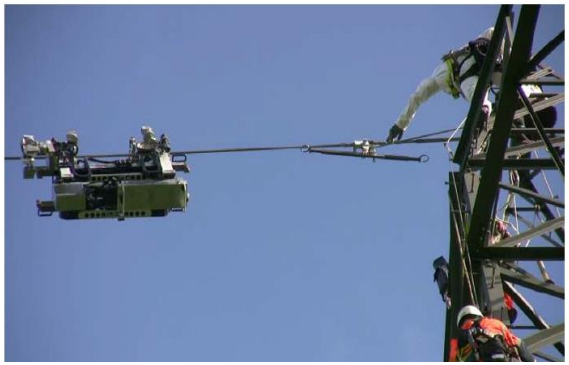
- The use of **robotics for maintenance**
- expected **climatic change:** consequences and influences on lines
- New and **alternative tower design** to increase the acceptance of overhead lines
- **Conductors** made of **new and non-metallic core materials** to work at higher temperatures to carry more electric current
- **Thermal Rating systems** to increase the capacity of existing lines depending on the present climatic **conditions**
- Especially for long connection: the use of direct current (DC) instead of alternating current (AC). A mix of both will be studied on a **"AC/DC hybrid line"** to use the advantages of both techniques
- Uprating of OHL by **increasing the voltage**

Robotics

Generally **not to take over the responsibility** from the maintenance staff.
But: to assist the maintenance staff

Used

- if too risky for personnel
- under poor access conditions
- unmanned helicopters for long distance checks
- robots for conductor check and small repair work



B2 Session 2013 Auckland, Symposium papers 262, 263

Multicopter

Small helicopters
1 pilot
1 observer

legal situation needs to be checked (permissions)

pictures: RTE (above) and APG / AIBOTIX (below)

video

Climatic change

Warmer, wetter and wilder??

- Warmer? YES – especially at northern latititudes
- Wetter? Depends on global circulations. Some areas may be dryer
- Wilder? – YES and NO!

We cannot allow ourselves to disregard significant changes in the climate in the future

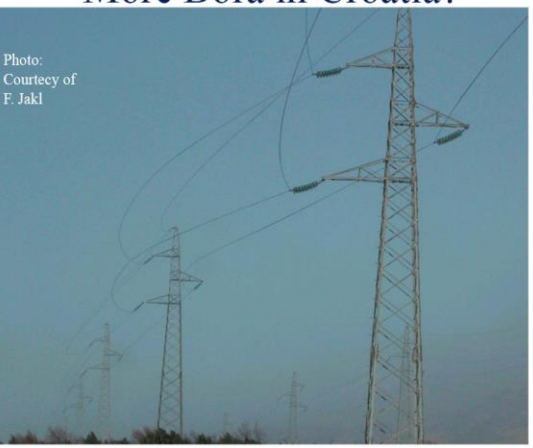
B2 Session 2013 Auckland, Symposium papers 122, 123, 125

WG B2.54	Management of risk associated with **severe climatic events and climatic change** on OHL

climatic change

- No consensus about effects and if: which and how severe
- Example: melting permafrost in Russia
- Example: in Norway less ice at the coats but more ice in the inland

More Bora in Croatia?



Melting permafrost in Russia?

More sub-water ohls in Iceland?

Pictures: Cigre, S. Fikke

Extreme weather conditions

Possible influences on OHL

- heat waves and droughts
- heavy rain
- ice and snow accreation
- storms, typhoons
- landslides
- floods
- hunderstorms

Pictures: Cigre
H. Hawes

Typhoon “Haiyan” at the Philippines November 2013

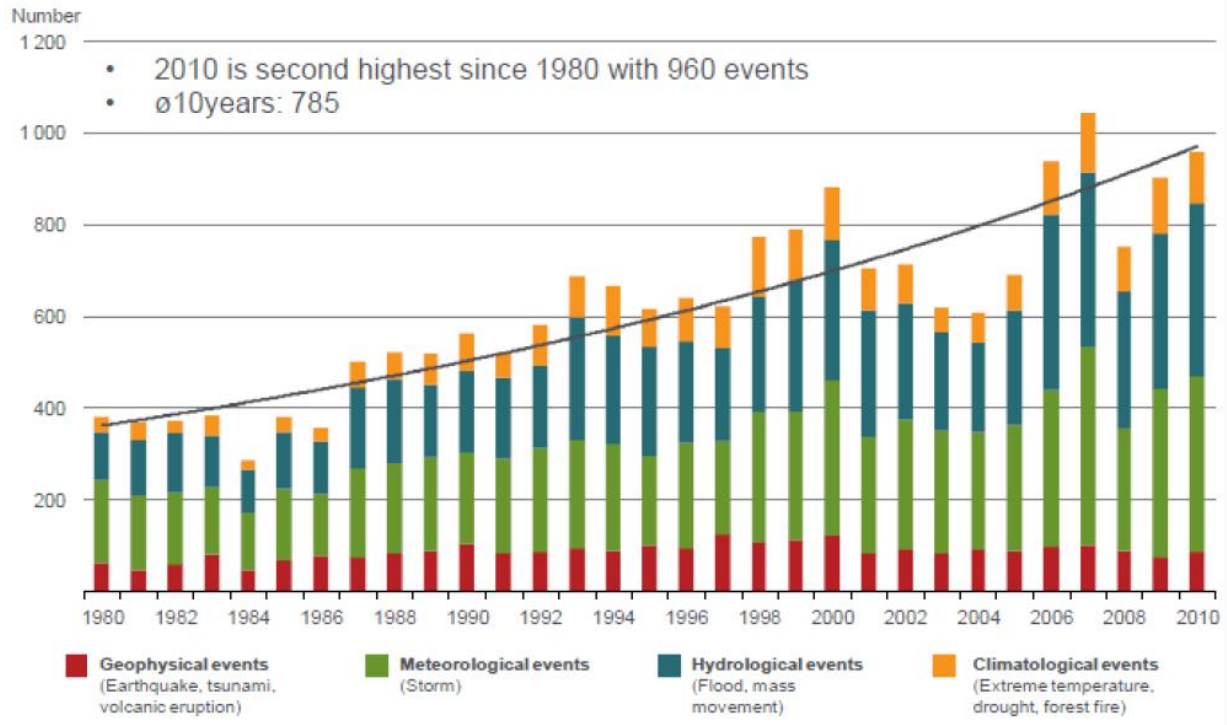
- Wind speeds up to 340km/h
- 600 km diameter typhoon
- Most severe typhoon ever

NatCatSERVICE

Natural catastrophes worldwide 1980 – 2010

Number of events with trend

Munich RE



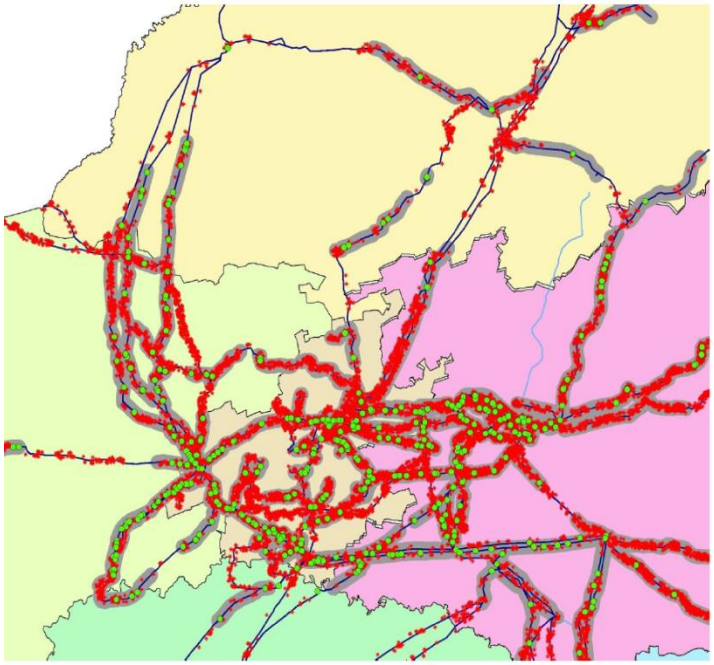
Climatic change (IPCC)

Intergovernmental Panel on Climate Change 2012

Example: extreme "Fire Weather"

- Aged and poorly maintained lines have a high risk of component failure causing fire
- Conductor clashing under strong winds in extreme fire weather also creates the increased risk exposure to fire starts
- Satellite observation (left: south Africa indicating OHL with actual fires near the line); right: Europe indicating actual fires)

Pictures: Cigre, H. Vosloo



Climatic change (concluding remarks)

- Evolution in climate must be accounted for (e.g. sufficient reserves in the design)
- Consider cheap actions (e.g. tower spotting) before you are forced to take on expensive ones (e.g. rebuild towers or re-route the line)
- Consider life time of OHL in relation to time scales for changes in climate
- Notify and file events in your grid

Picture: Cigre, S. Fikke

Alternative tower design

To increase the acceptance of OHL

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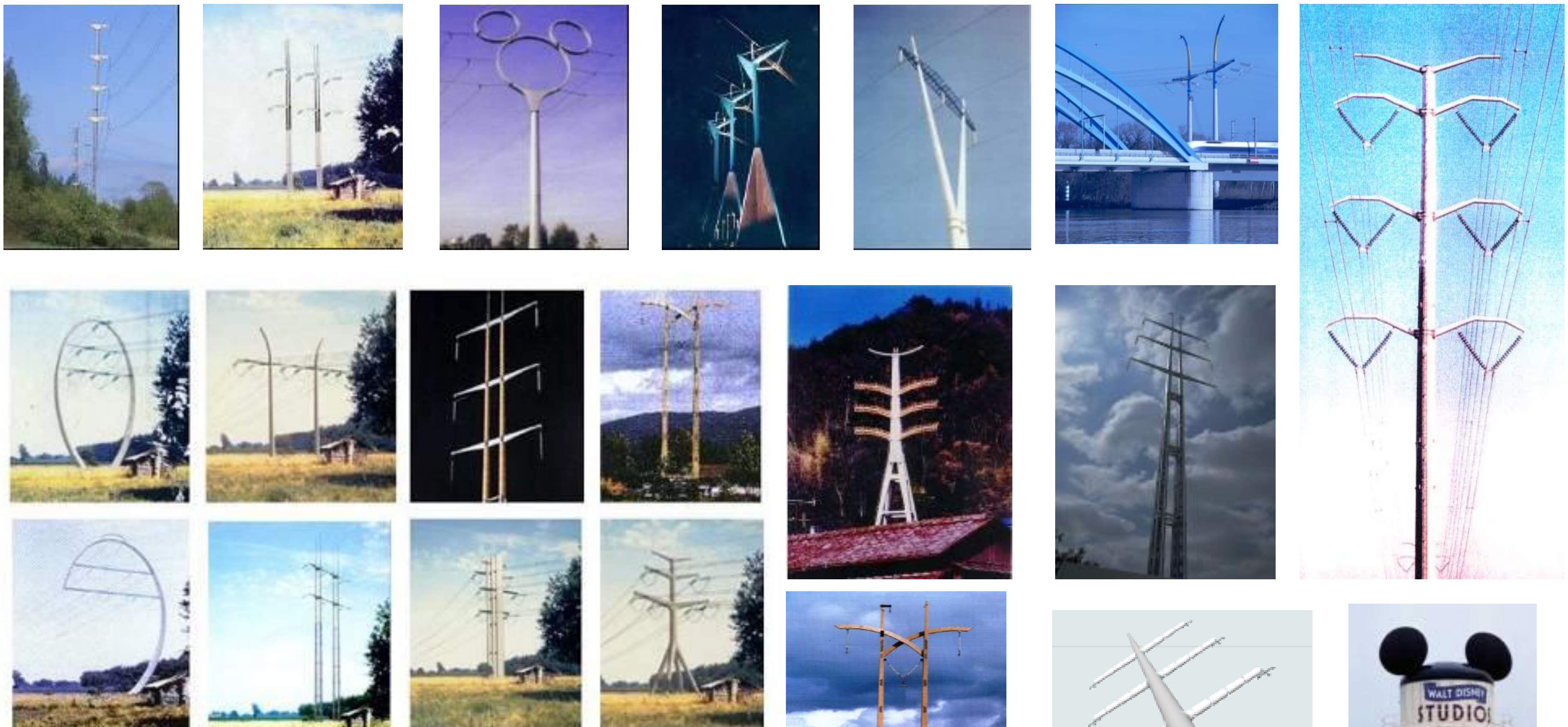

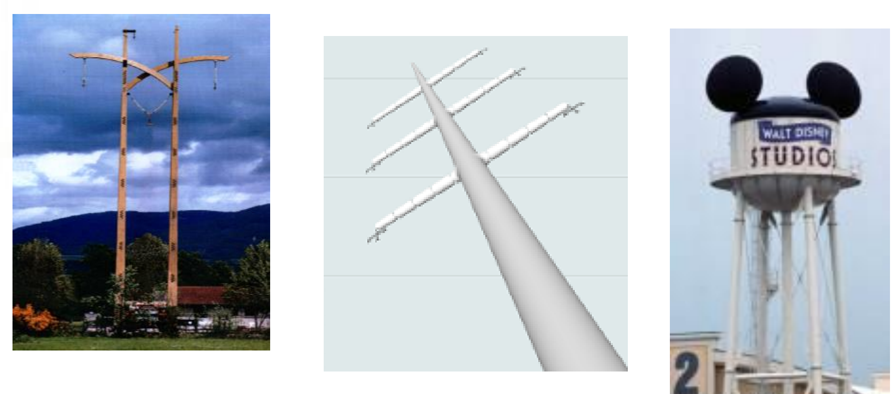

pictures: Cigre, Joao da Silva, P. Meyer EDF/RTE, T. Sörensen energinet, fingrid, REE, www

tower design competition
Iceland

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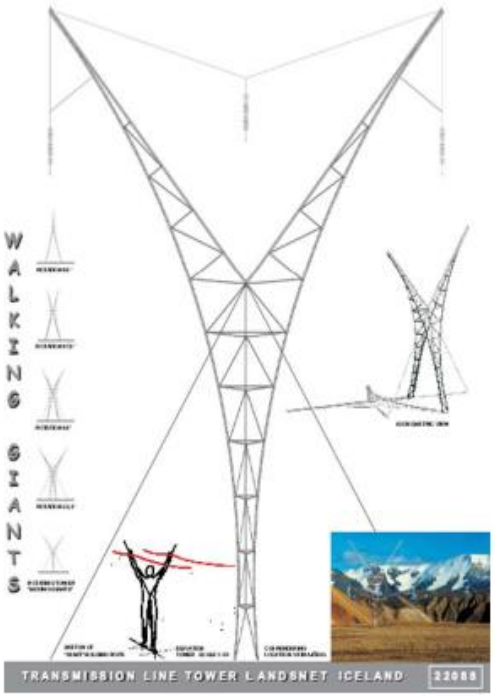


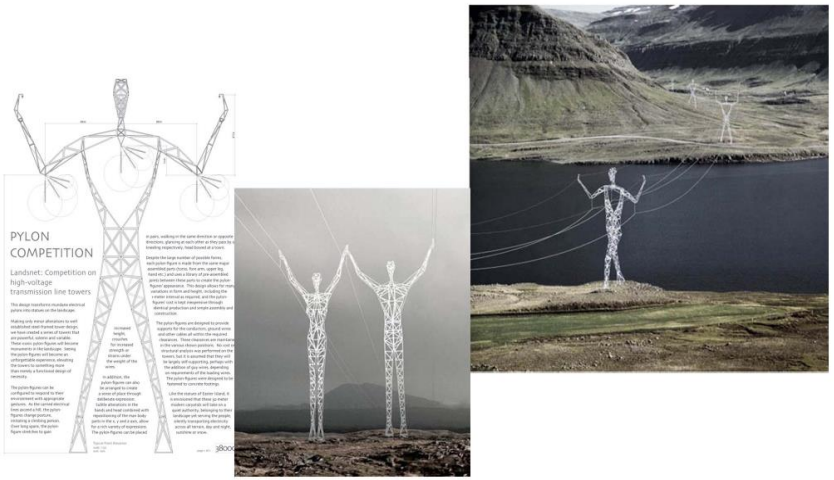
1. Prize – Tower

2. Prize - Sculpture

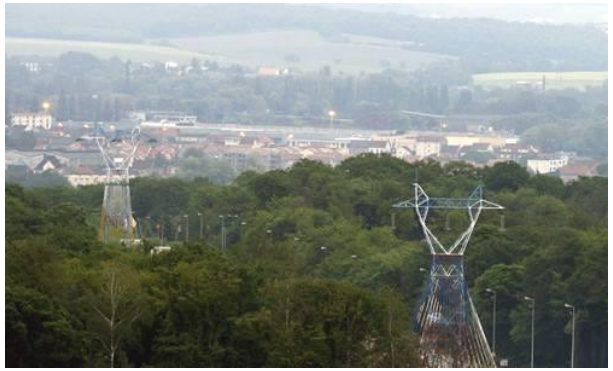
Pictures: Cigre, Session 2011 Reykjavik

Other ideas – **Iceland, France**

Human Pylon Sculpture Mast (Landsnet)



RTE, Amnesville



Pictures: Cigre, Session 2011 Reykjavik; RTE (E. Paroucheva)

tower design competition
Norway, **Iceland**

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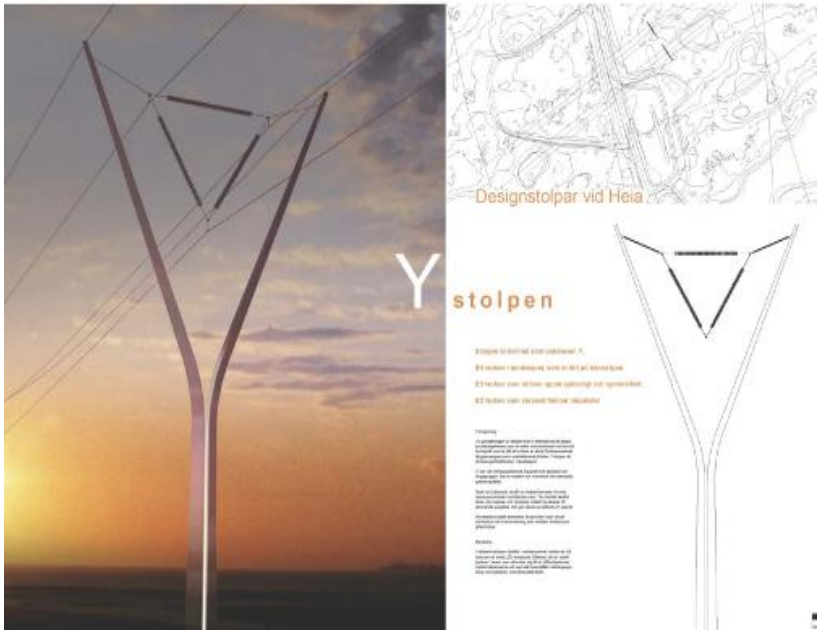
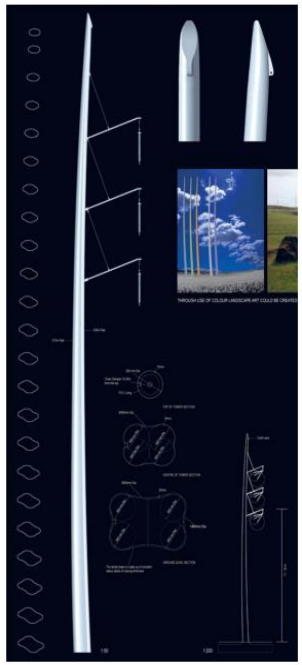
The Y-mast (Statnett)



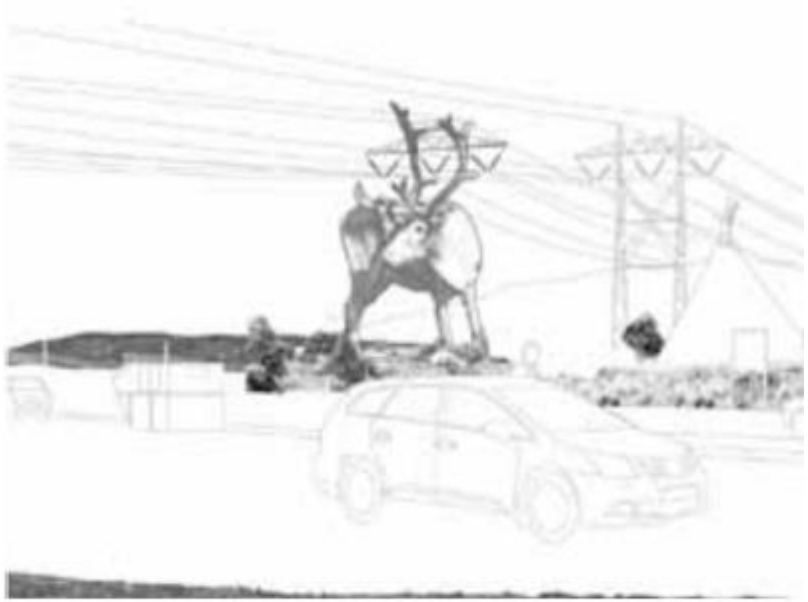
The Fishbone Tower (Landsnet)



Pictures: Cigre, Session 2011 Reykjavik

tower design competition
Norway

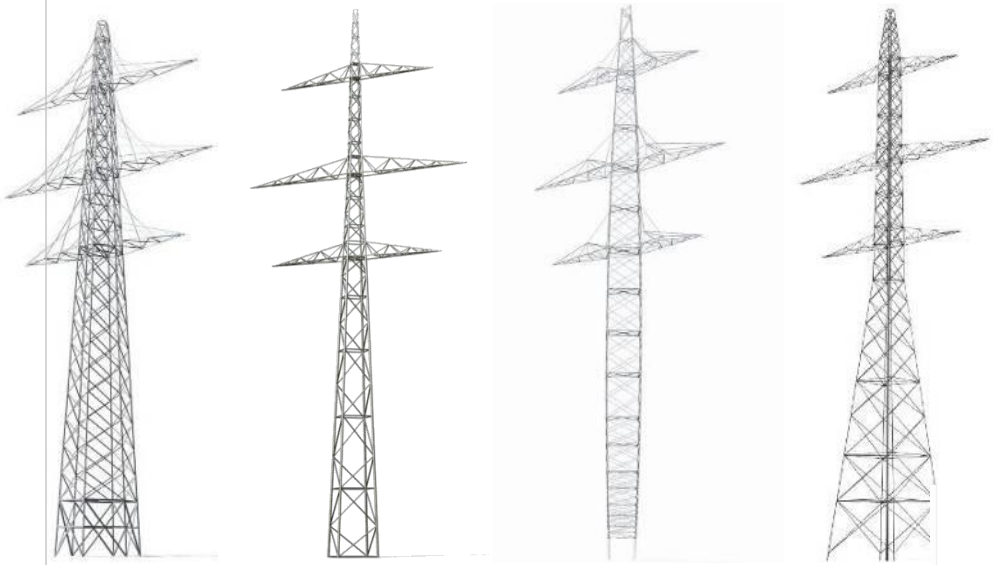
1. Prize – Sculpure

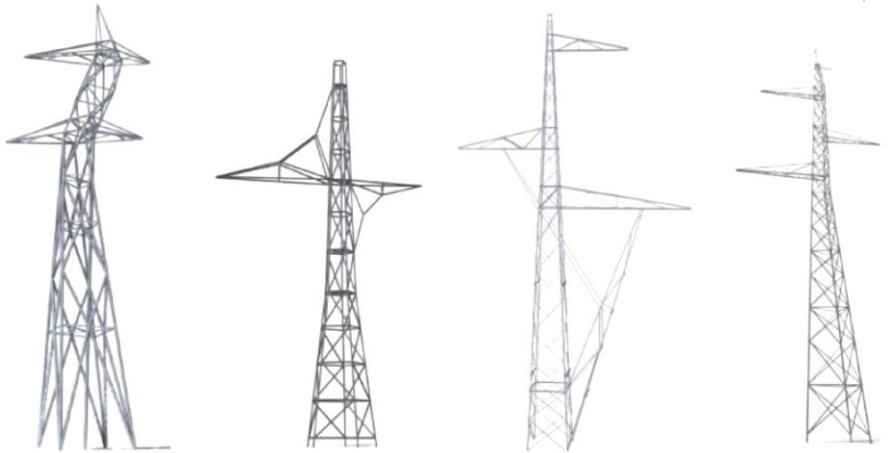


2. Prize - Sculpture

Pictures: Cigre, Session 2011 Reykjavik

Design study from University of Arts SCIONIC / Linz / AT





400kV lines
Lattice steel tower is optimized

new tower design

the Netherlands, Tennet, Randstad

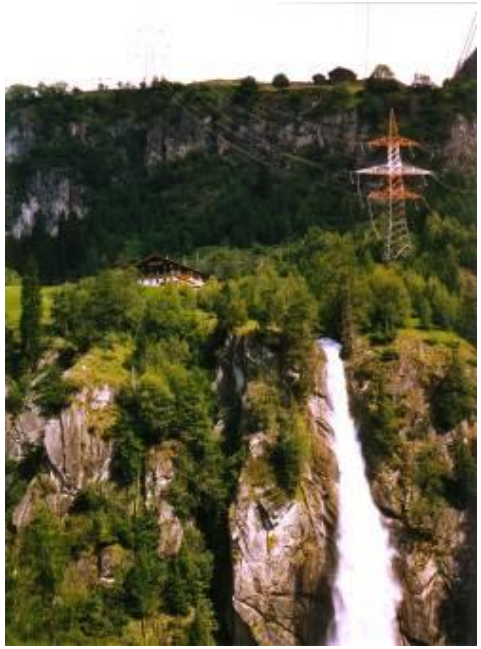
2 x 400kV lines
also: 2x 110kV + 2 x 400kV
Paper at Cigre 2014 Paris

Example: compact line 420 kV - Dubai (since 2008)

Comparison of standard and compact line design
2 x quadruple bundle

Picture: Cigre, Session 2010 Paris B2-112, F. Schmuck

different acceptance of OHL



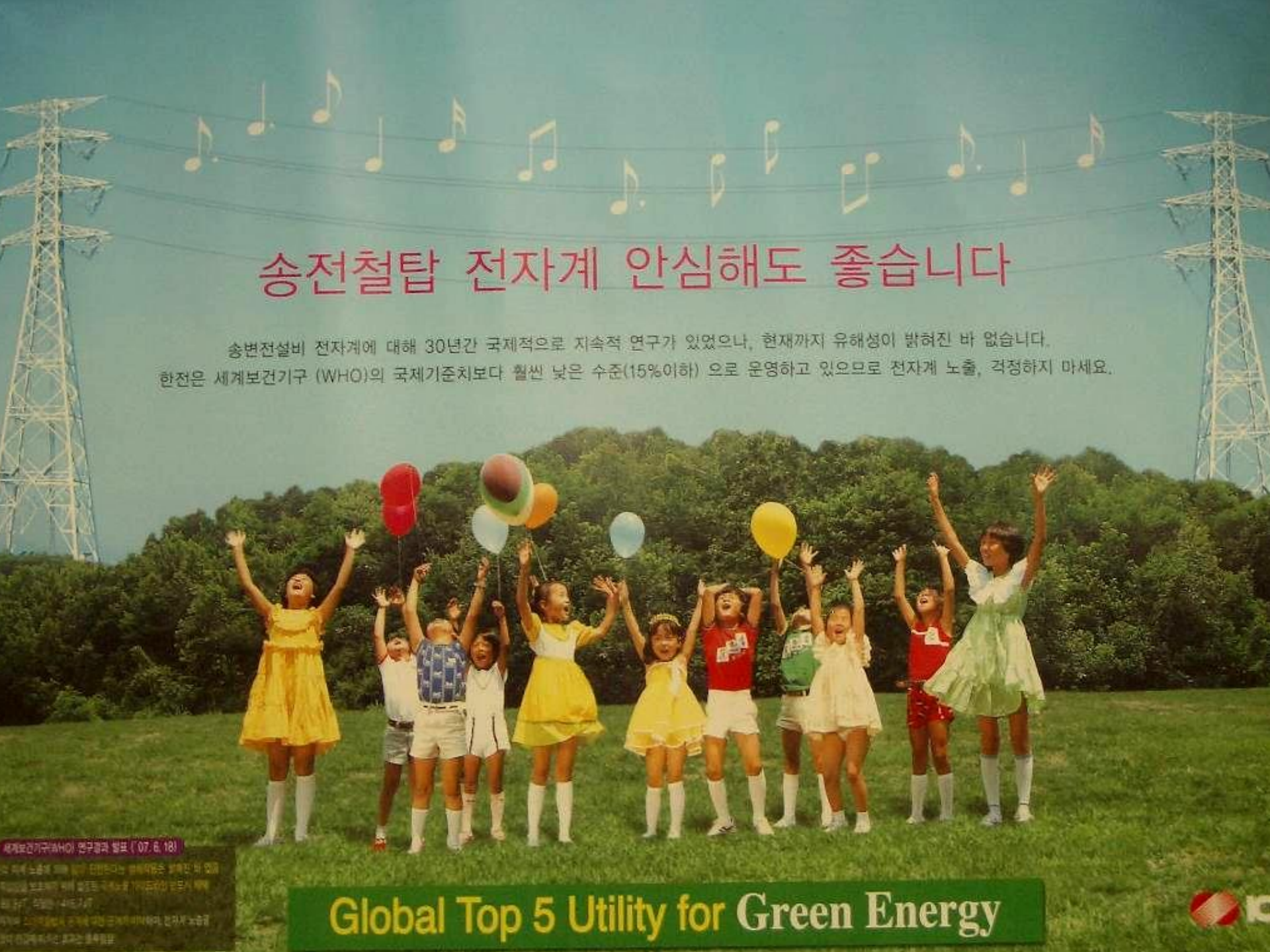
red – white red coloured towers not disturbing (Austria)

Nest for storks

Military side effect (Italy)

line not disturbing? (Germany)

B2 members taking pictures


송전철탑 전자계 안심해도 좋습니다
송변전설비 전자계에 대해 30년간 국제적으로 지속적 연구가 있었으나, 현재까지 유해성이 밝혀진 바 없습니다.
한전은 세계보건기구 (WHO)의 국제기준치보다 훨씬 낮은 수준(15%이하) 으로 운영하고 있으므로 전자계 노출, 걱정하지 마세요.
Global Top 5 Utility for Green Energy

New conductor materials

Principle: conductors which allow a higher service temperature (more than 80° C) to transport more current. 150/180/210° C

challences

- not much increase of sag
- similar tension forces
- thermal capability of the materials
- no or only little adaptions on existing towers
- Substations must allow higher current
- Check the legal situation (permisson) to run the line with the desired current

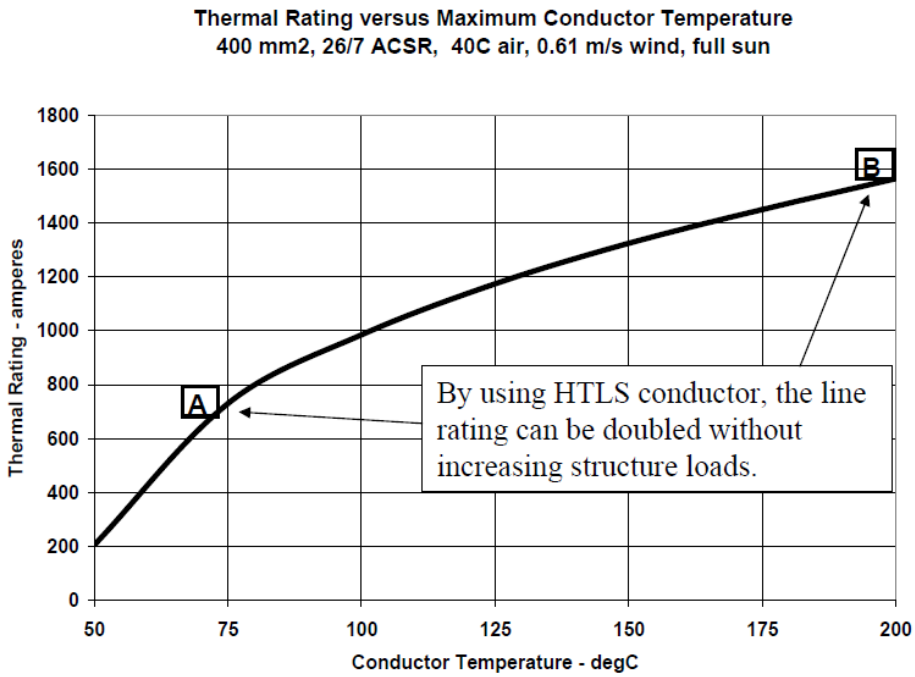


Diagramm: Cigre, D. Douglass

WG B2.42	Guide to Operation of Conventional **Conductor Systems above 100°C**
WG B2.55	Conductors for the **Uprating of existing Overhead Lines**
WG B2.48	Experience with the mechanical performance of **new conductor types**

New conductor materials

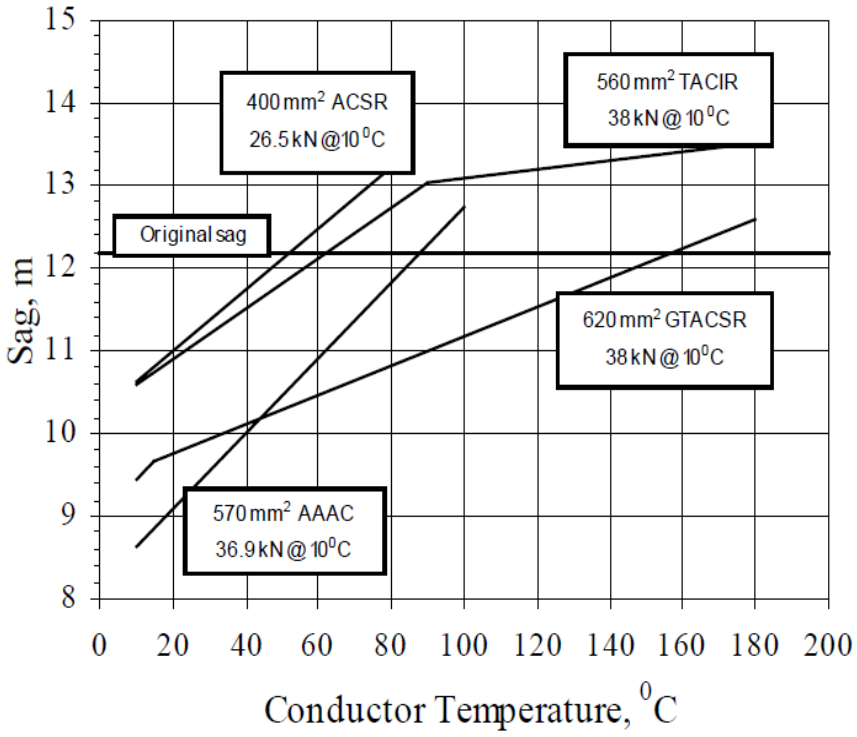


Diagramm: Cigre, Session 2000 Paris 22-202

Next step: conductors with „knee point“ to reduce the increase of sag with temperature

Temperatures up to 250° C

At temperatures above the „knee point“ the sag does not increase linearely.

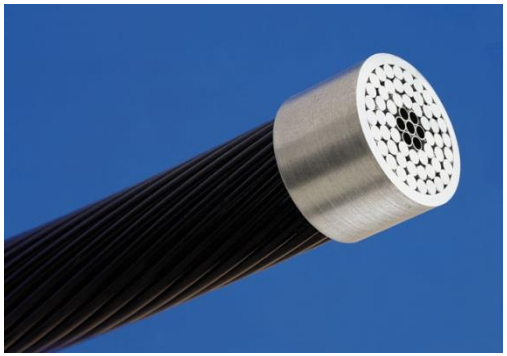
New conductor materials

overview on conductor types (not complete)

- AAAC All Aluminium Alloy Conductor
- ACSR Aluminium Conductor Steel Reinforced
- TACSR Thermal resistant Aluminium Conductor Steel Reinforced
- G(Z)TACSR Gap-type (Super) Thermal resistant Aluminium alloy Conductor Steel Reinforced
- (Z)TACIR (Super) Thermal resistant Aluminium alloy Conductor Invar Reinforced
- ACAR Aluminium Conductor Alloy Reinforced
- ACSS Aluminium Conductor Steel Supported
- ACCC Aluminium Conuctor Composite Core
- ACCR Aluminium Conductor Composite Reinforced

Picture: 3M, ACCR

Picture: CTC, ACCC



Picture: Lumpi-Berndorf, TACSR (coated)

New conductor materials

When speaking about high temperature conductors also the losses need to be considered:

- The current losses are 4 times higher if the current is doubled
- The total losses rise more than that as the conductor´s resistance rises with the temperature.
- Therefore the total losses of a high temperature conductor at full load are app. 6 times higher compared with a „standard“ ACSR (example for a conductor ACSR or AAAC 340/110 at 80° C)

Thermal rating systems

The ampacity of an overhead line depends on several factors

- clearances to ground , buildings, obstacles
- maximum allowable conductor temperature (mechanical)
- substations must be prepared for higher current
- load flow considerations of the grid
- legal situation (permisson) to run the line with the desired current

The actual temperature of the conductor depends on the ambient conditions and the electric current

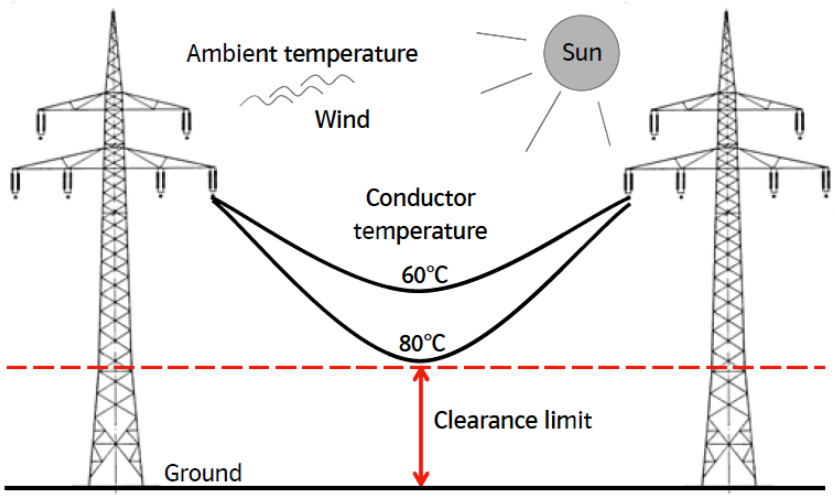
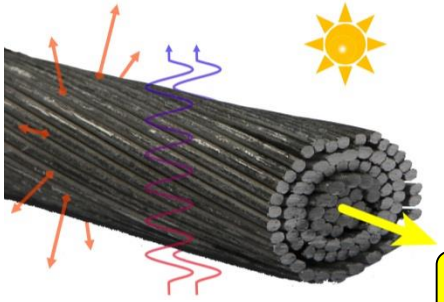


Figure 1: Clearance depending on ambient conditions and current

Picture: Cigre 2008 Paris B2-101

WG B2.43	Guide for **Thermal Rating Calculations** for Overhead Lines with high temperatures and real-time weather & load data

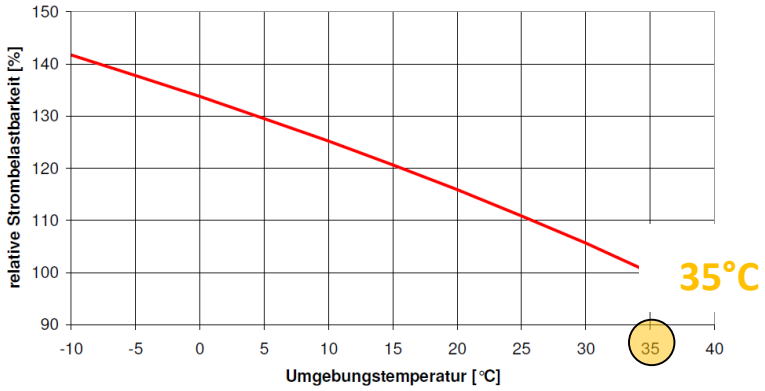
Influences on conductor temperature



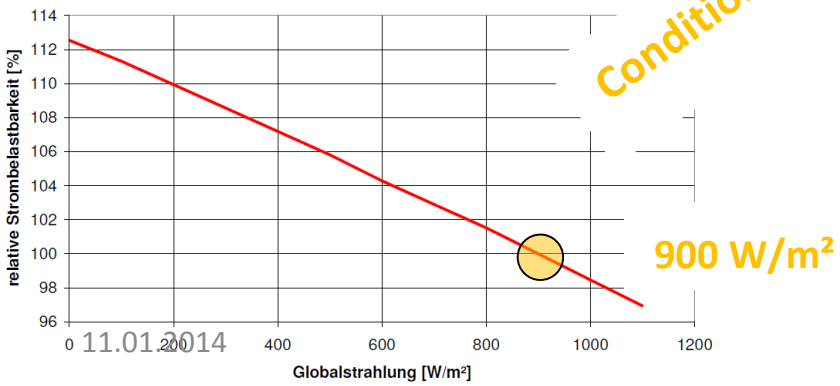
Electric current

Conditions from standards

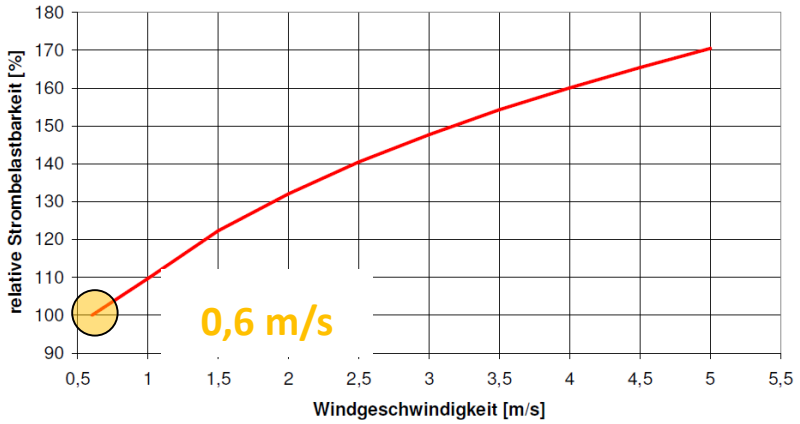
ambient temperature



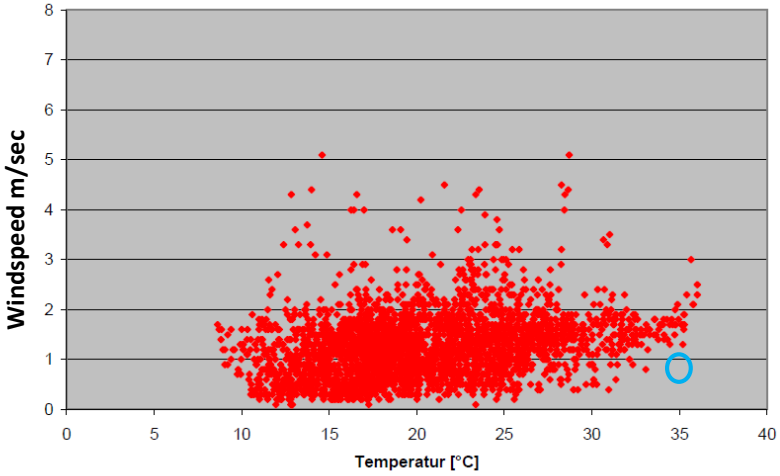
global radiaton

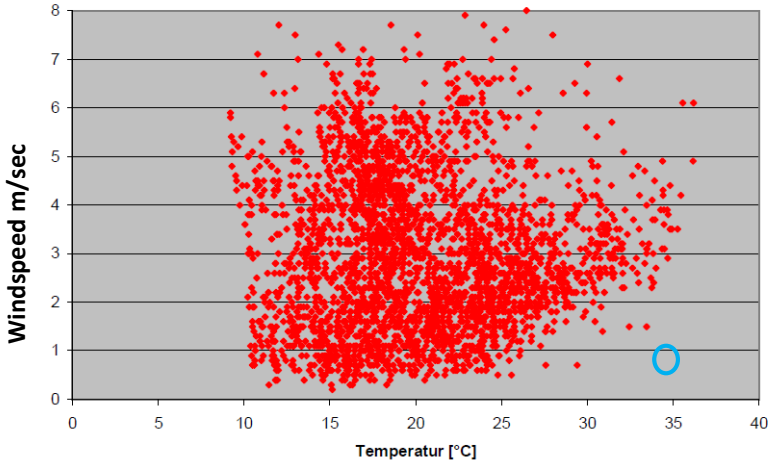


windspeed and direction



Wind speed and temperature at summer 2007 at two locations in the European Alps





Example: Blue values are examples from standards Wind 0,6 m/sec, ambient temperature 35° C.

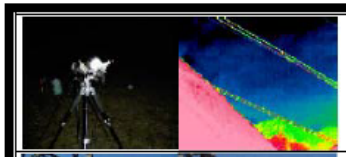
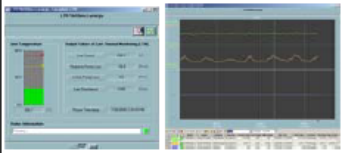
When the ambient conditions are different, the line can be loaded higher

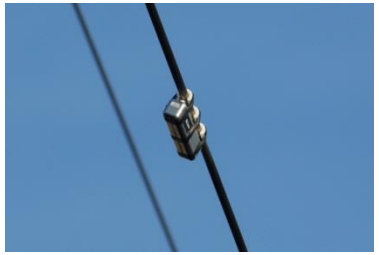
Thermal rating depends on the environmental situation. It does not substitute the transmission line development.

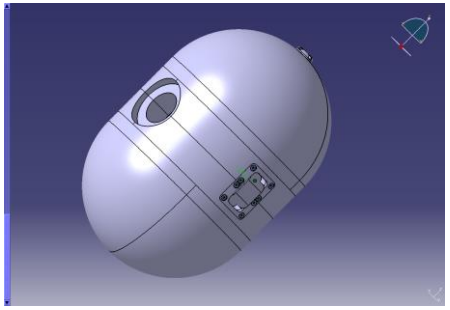
Table: example, no general statement!

ambient temperature	wind speed (rectangular)	Ampacity
35°C	0,6 m/sec	100 %
20°C	0,6 m/sec	115 %
20°C	2 m/sec	150 %

Thermal rating methods
(examples)

	**Thermo-vision** measures infrared part of the wave spectra. Line conductor temperature can be obtained by mapping the colour information into the corresponding temperature spectra
	The **CAT-1** system is based on the mechanical tension measurements between the tower and the isolator in combination with solar radiation and outside temperature measurements. These measurements are hot spot measurements.
	The **SAW** measurement measures the surface acoustic wave. This method is developed by the University of Darmstadt. The sensor is fixed on the cable and sends the data to a communication unit. Of course this is a hot spot measurement.
	The **WAM/LTM** is based on PMU-measurements. The temperature can be calculated from the changes of the line resistance. This is the only system which delivers an average value of the line temperature and with the time resolution of 1 second.
	**Meteorological** measurements are performed on the level of the line conductor. Temperature, solar radiation, wind and humidity are recorded.
	For direct sag measurement, **laser** and **radar** measurements were tested. These measurements are also hot spot measurements





Pictures: Cigre, Session 2006 Paris B2-311; Ampacimon, MICCA

AC/DC hybrid lines

Existing 2 x 400kV AC line will be changed to:

- 1x420kV AC
- 1x +/- 400kV CD

Investigations about influences from ion currents

Interaction AC-DC and DC-AC ?

Influences in substations (e.g. transformers)

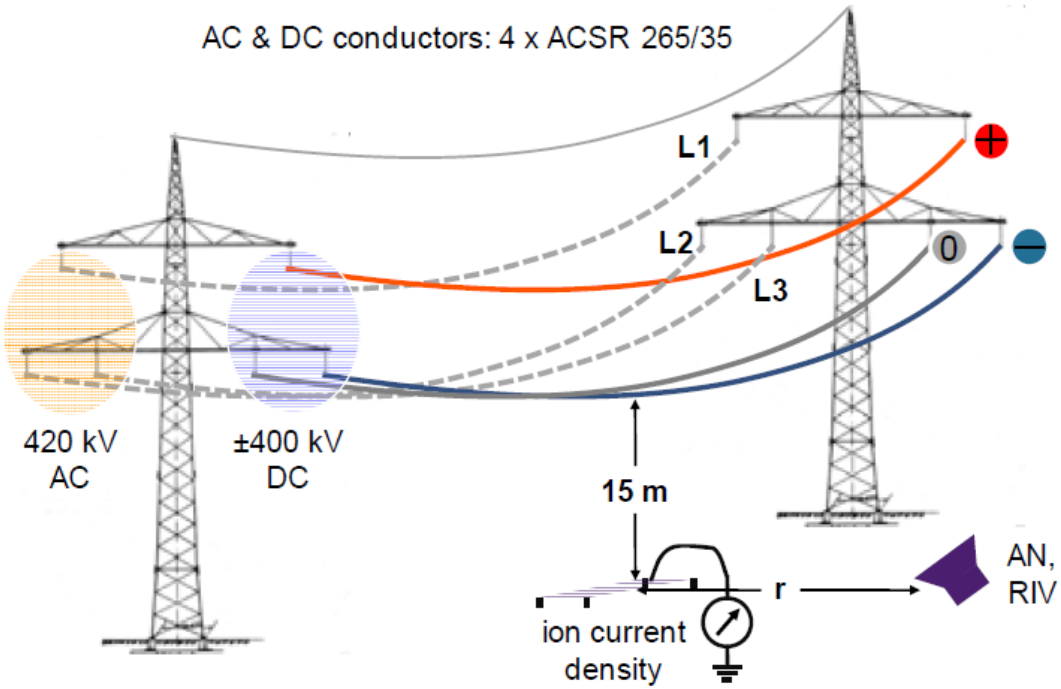


Figure 4: Line configuration for AC-DC conversion

B2 Session 2013 Auckland, Symposium papers 141, 142

WG B2.41	Guide to the **conversion of existing AC lines to DC operation**

Voltage uprating

Example: uprating of a 300kV line to 420kV (**Norway**)

- Additional 40% capacity
- Uprating of a major portion planned (20% shall be uprated in 2030)
- Relatively small visual changes
- The world´s largest uprating project

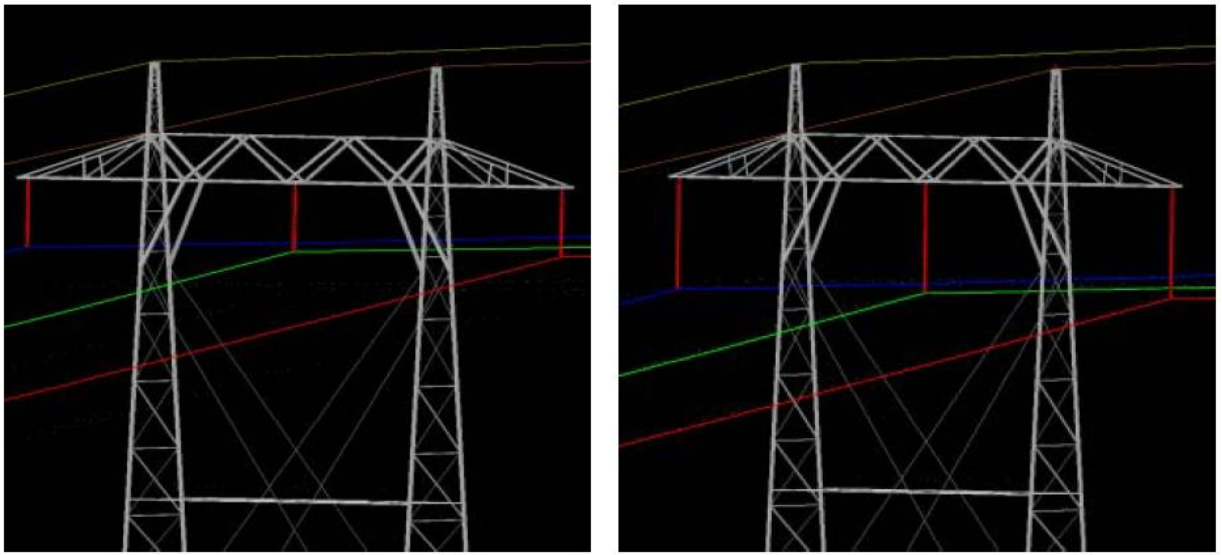


Figure 7. Left: The line before uprating. Right: First proposal for uprated line.

Cigre session 2012 Paris, B2-102-2012

Symposium, Tutorial, Colloquium

11TH INTERNATIONAL EXHIBITION OF ELECTRICAL AND INDUSTRIAL ELECTRONICS INDUSTRY
ELECRAMA-2014
8-12 JANUARY 2014, BIEC, BANGALORE, INDIA

Example: **International Colloquium on Ultra High Voltage in association with CIGRE April 2013 in New Delhi**

Example**: September 2013 Cigré B2 Session in Auckland/New Zealand**

100 papers and more than 350 attendees from 35 countries

Symposium

- Extreme weather and environmental conditions (heavy rain, humidity, seismic, etc.)
- Lifetime management, asset management, maintenance techniques
- Upgrading and uprating of Transmission and Distribution asset
- HV and MV equipment
- New requirements for combined AC & DC networks

Tutorial

- Methods for the optimized design of overhead transmission lines
- Transmission Line Upgrading with High-Temperature Low-Sag (HTLS) Conductors
- Engineering Guidelines Relating to Fatigue Endurance Capability of Conductor/Clamp Systems
- Evaluation of Aged Fittings

How does Cigre work?

a) Discussion of "preferential subjects" (items of general interest, new developments, at the Paris session every 2 years (even years)

- Definition of "preferential subjects" for each SC
- Submission of suggested contributions from SC members to TC of Cigre (acceptance or refusal)
- "Special reporter" system
  - The Special Reporter poses questions prior to the meeting (published on www)
  - Answers and discussion at the meeting

b) Production of technical brochures

- Study committee meetings – yearly (in Paris in even years and elswhere in odd years)
- Working Groups (incl. task forces) produce Working Group documents
- Confirmation of WG documents - after revision and discussion by the SC as Cigre paper
- Publication

c) Seminars, Tutorials, Colloquiums

- about pending questions/developments, new materials, methods, approaches
- With practical reference for the transmission line engineer

Preferencial Subjects
2014 Paris Session

11TH INTERNATIONAL EXHIBITION OF ELECTRICAL AND INDUSTRIAL ELECTRONICS INDUSTRY
ELECRAMA-2014
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PS1 Minimizing the Impact of new Overhead Lines

- Design, construction and operation
- Ecology, vegetation and wildlife management
- Routing and visual acceptance
- Design of, and experiences with, transitions to underground sections

PS2 Reliability and Design Optimization

- Tools and methods
- Impact of different designs on initial and life cycle costs
- Cost effects of environmental, regulatory and public influence

PS3 Conductors : Installation and Long Term Performance

- Installation, maintenance and replacement methods including
- live line techniques
- Creep and fatigue issues on new conductor types
- Mechanical behavior of new bundle configurations

B2 Green Book

B2 will issue a „green book“, planned for 2014.

It shall present the main topcs of the OHL business in an easy readable manner.

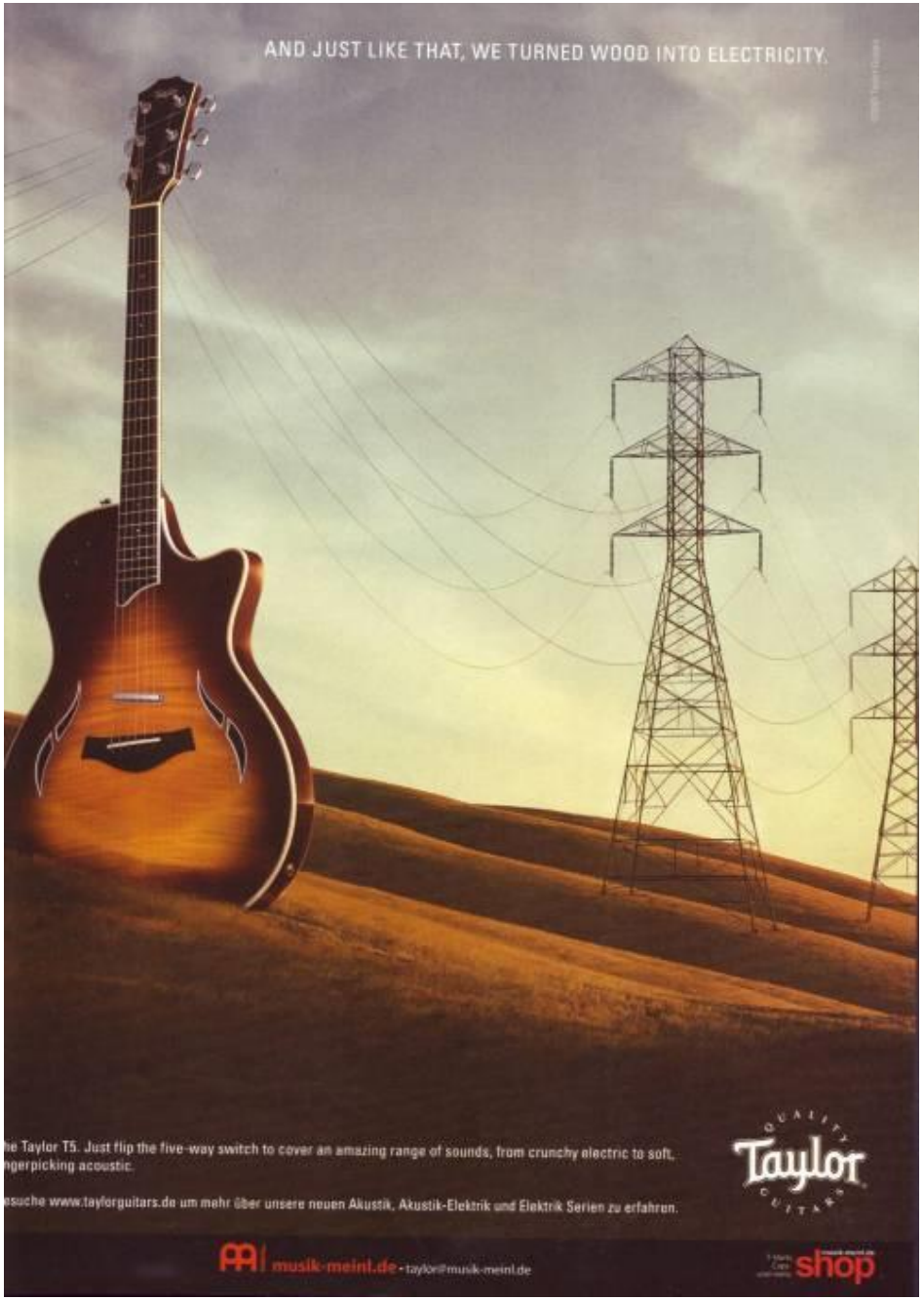
The basic priciples will be given but also new developments will be presented.

Comparison OHL and UGC

2015 Session in Delhi

between Februar and May 2015?

Eventually can be held along with Grid Tech 2015 biannual Exhibition



Radical new tower design ?

Voltage uprating

Phase 1:
Line as it is today

- LiDAR scanning
- Pictures
- Line inspections
- Adjustments for actual height, load, insulator configurations, orientation

Phase 2:
First uprating proposal

- Standard insulator configurations
- Clearance checks with deterministic method
- Identification of 'problem towers'

Phase 3:

Final uprating proposal

- Fine tuning of insulator configuration
- Probabilistic check of line performance

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