CIGRE SEERC Workshop

ARE OHL'S REALLY UGLY OR WHAT TO DO TO MAKE THEM MORE ACCEPTABLE?

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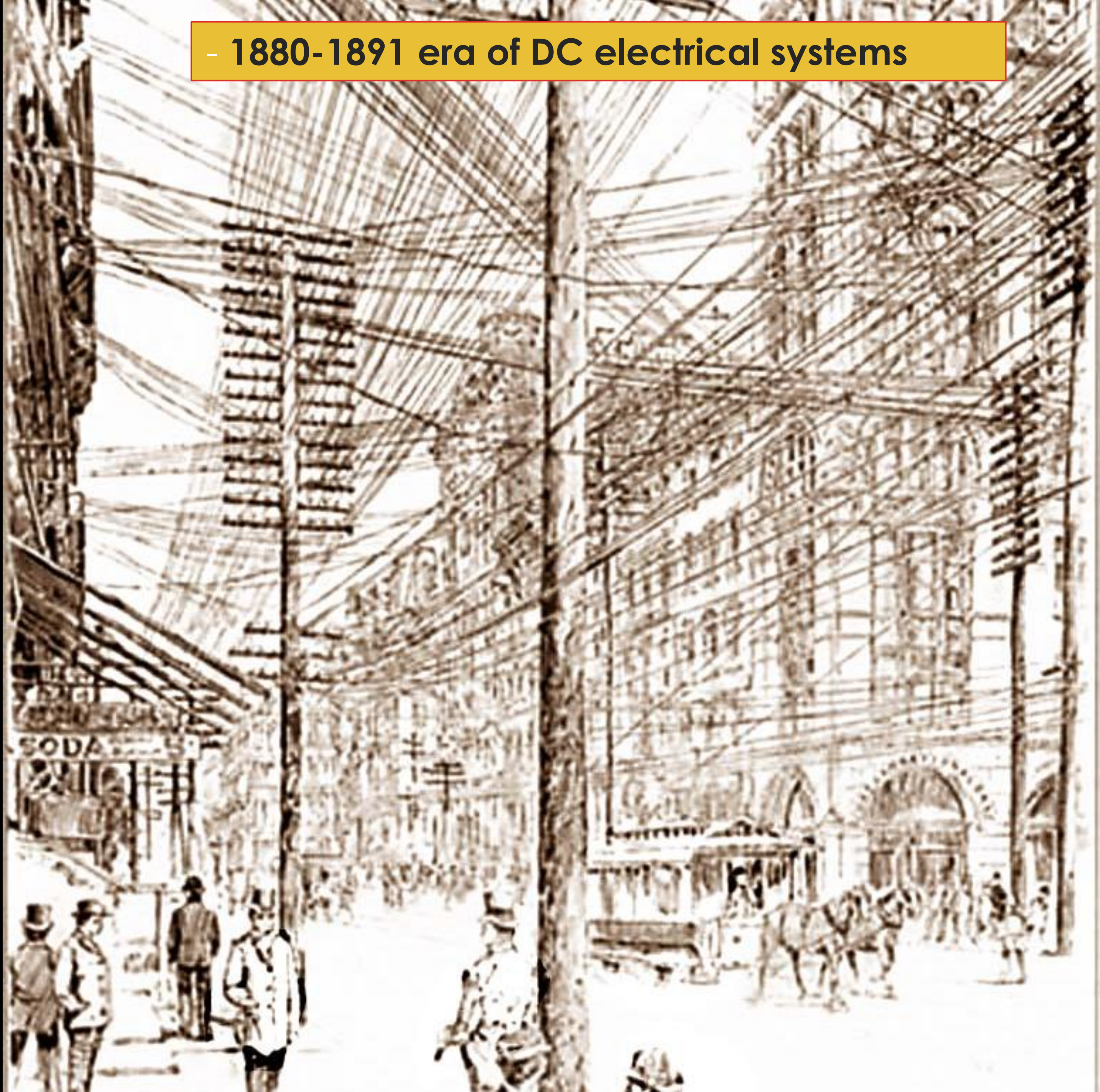
HOW WAS THE BEGINNING OF THE OVERHEAD LINES PRACTICE?

WORLD

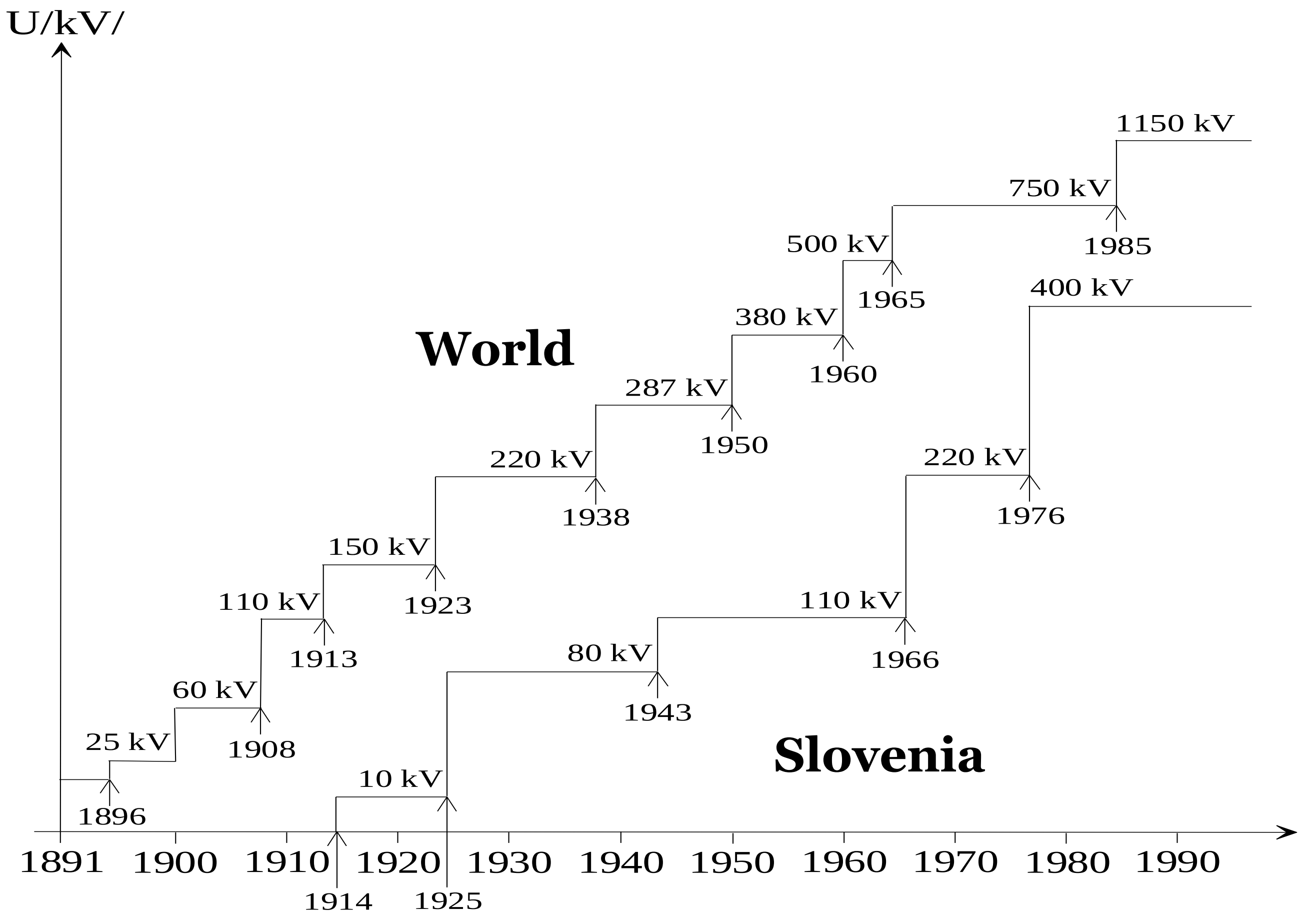
-First DC OHLs in 1882
-First AC 3Phase OHL, 1891
-First OHL over 110 kV, 1910
-First OHL over 400 kV, 1952
-First OHL over 1000 kV, 1985

At beginning the first TT and electrical DC 110 V lines were on same poles.

- 1880-1891 era of DC electrical systems



Kresimir Bakic



Increasing Voltage levels

Important innovations:

- Conductors (1899…*stranded AL conductors ;* ***1907*** *…ACSR, 1939 AAAC*)
- Insulators (***1907***…*first suspension and strain types; first OHL over 100kV*)
- Generators units size (***1911***…*Ludwig Roebel (BBC), Invented stator bars for turbo generator, enables first large generators over 20 MVA)*

Krešimir Bakič

NETWORK DEVELOPMENT – OVERHEAD NETWORKS OVER 95%

WHO CARES ABOUT ENERGY TRANSITION or STRATEGIES, IF MY OUTLET BOX ALWAYS HAS ELECTRICITY

At the beginning of the OHL practice, there were no "ugly" or "beautiful" pillars for overhead lines. The point was just to get electricity.
The first major changes occurred in the 60‘s of the last century. Electricity is no longer an "privilege" of individuals, but an obligation on the state towards citizens who have a "right" to electricity. In 1981, CIGRE organized for the first time in its history the Symposium on the impacts of the OHLs on the environment and vice versa.

Until 1980, we calculated the time from the decision for construction certain objects to final construction: for TPP (7 years), and for OHLs (3 years). After 1990, the time for TPPs was shortened, and for OHL it increased several times.

2. What is the situation around the world today?

Spatial placement for new OHL's as well as upgrading old OHL's are part of the most problematic and long-lasting process, despite very friendly legislation in some countries (e.g. Germany, France).

Where are the problems and how to proceed?

Liberalization of the electricity market, further electrification, orientation to RES, energy efficiency, and introduction of Smart Grids technologies require **more network connections**, more OHLs and cables. **The non-carbon society of the future** will rely on a robust and flexible **multi-level** power system (new AC-DC, different power sources, Load flows, Information flows, Money flows, Grid of control structures) with millions of renewable sources. This will need more OHL, more undersea cables, better cooperation between systems for cheaper electricity.

What were results of last Cigre study of WG C1.44 ?

- **More interconnections cheaper electricity (OHLs & undersea cables)**
- **More Renewable sources – cheaper electricity and less CO_2 emissions**

What are the problems of new OHL‘s?

- Environmental restrictions (aesthetic influences, EMF impacts)
- Techno-economic constraints (New technologies…)
- Value of real estate in the vicinity of OHL, cost socialization,…

3. Siting issues for overhead lines

Proposal for the most suitable route (which is basis for state locational plan) is determined by criteria in accordance with National decree on the Spatial order on certain country. This consists for many countries the following requirements:

1. **Functional aspect** (technical and technological characteristics and implementation possibilities)**,**
2. **Aspect of rational use of space** (assessment of suitability for spatial development of a wider area),
3. **Environmental protection aspect** (assessment of suitability for nature conservation, environmental protection, protection of cultural heritage),
4. **Economic aspect** (assessment of the costs of implementing spatial planning, compensation, benefits, ...), and
5. **Acceptance aspect in the local social environment.**

4. Environmental impacts of the OHL‘s

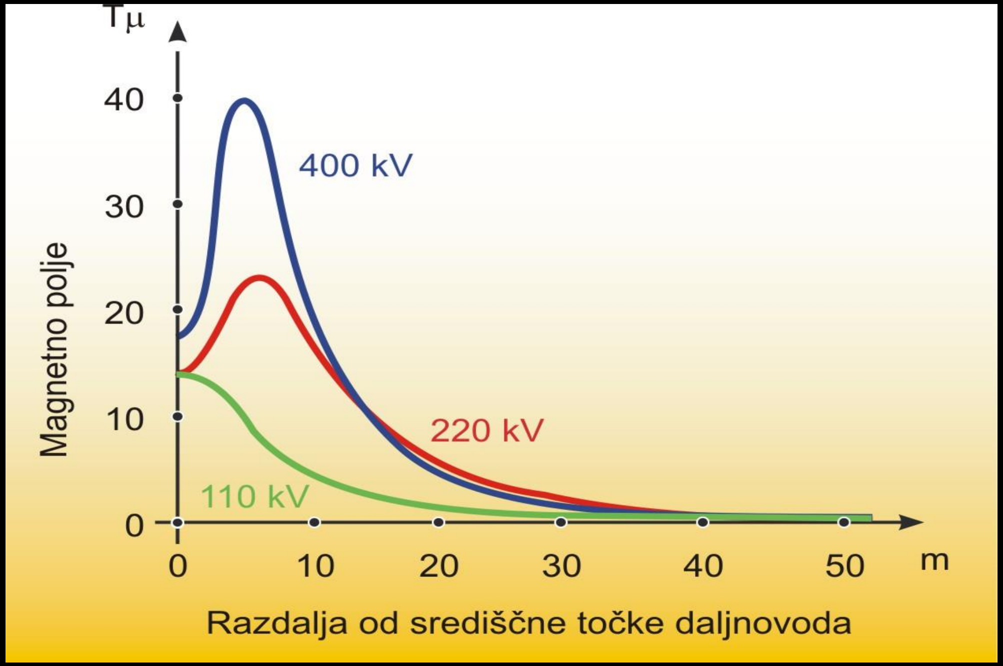
The strength of the Earth's natural magnetic field: 30 – 60 μT
The strength of the natural electric field of the Earth: ca. 100V/m.… depending on the time

Electromagnetic influences in Slovenia by law

	Limit value for magnetic field (μT)	Limit value for electric field (kV/m)
I. zone (kindergartens, hospitals…)	10	0.5
II. zone	100	10

The limit values set by the legislation for new and reconstruction resources are **10 and 20 times stricter** than the limit values for existing radiation sources:
0,5 kV/m and 10 μT (for Zone I — new sources and reconstructions).

Regulation on Electromagnetic Fields in the Natural and Living Environment



Distances from the axis of the OHL

1150 KV SUBSTATION IN TOGLIATTI, RUSSIA 1989

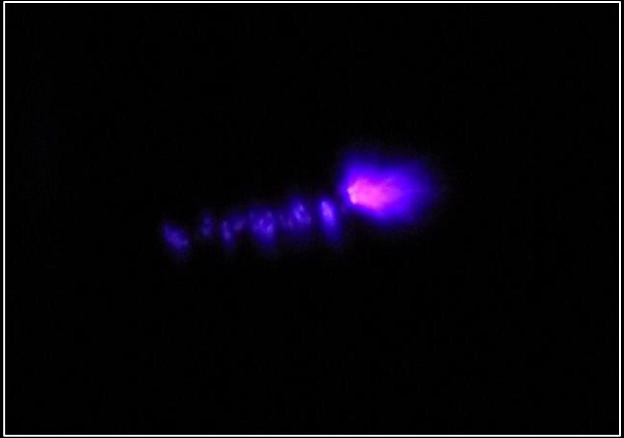
Electrical field
was 30 - 40 kV/m

Visit of the Slovenian experts at the Russian test switchyard 1150 kV in Togliatti.

5. Noise effects

Corona

Ionization of air on the surface of the conductor due to exceeding the critical value of the voltage gradient. Noise depends on air density, as well as weather conditions.



Limit values for noise indicators (SI)

Noise protection area	*L (day)* [dBA]	*L (evening)* [dBA]	*L (night)* [dBA]
IV. level	73	68	63
III. level	58	53	48
II. level	52	47	42
I. level	47	42	37

II. Level of Noise protection : surfaces where no noise-disturbing environmental interference is permitted (**hospitals, health resorts, convalescent homes, clean residential areas, holiday homes, tourism**

III. Level of Noise protection : for the following areas of more detailed land use, where interference with the environment less disturbing due to noise production is permitted **(housing area, social infrastructure, green spaces (recreation, parks, cemetery), mixed area, area of water land)**

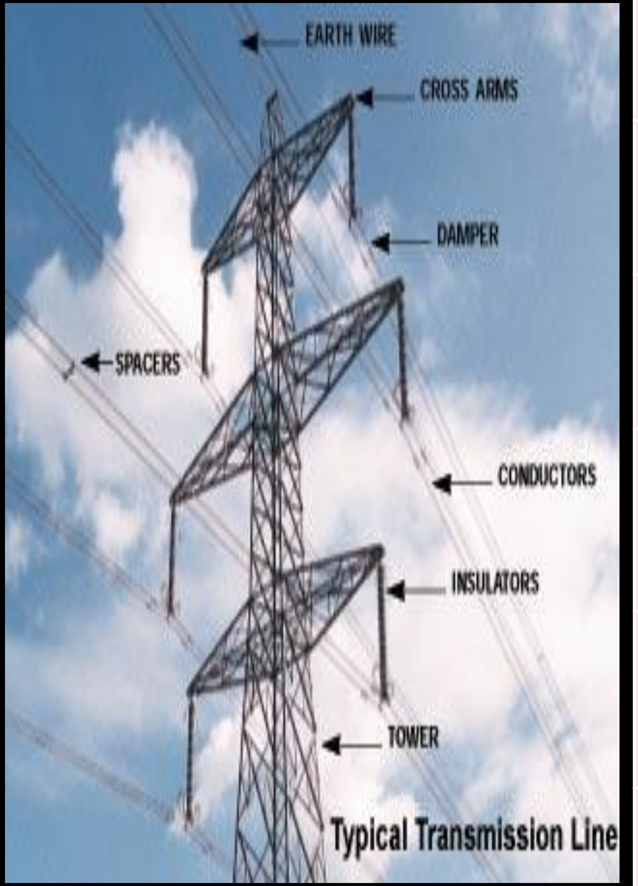
EN 50341-1 in chapter 5.5 defines Corona effects: Radio noise, limits and Corona losses. (see NNAs)

Example of noise for 400 kV DV: 2 or 3 conductors per phase

MINIMUM DISTANCES FROM OHL AXIS REQUIRED FROM INDIVIDUAL NOISE PROTECTION ZONES FOR THE NIGHT - TIME

Noise protection level	Voltage between phases [kV]	Safety height of conductors [m]	Nighttime limit values [dB(A)]	Distance from the OHL axis of 2 conductors in phase [m]	Distance from the OHL axis of 3 conductors in phase [m]
I.	420	8	37	142*	11
II.			42	**142**	**11**
III.			48	65	0
IV.			63	0	0

How pillar design can mitigate impacts



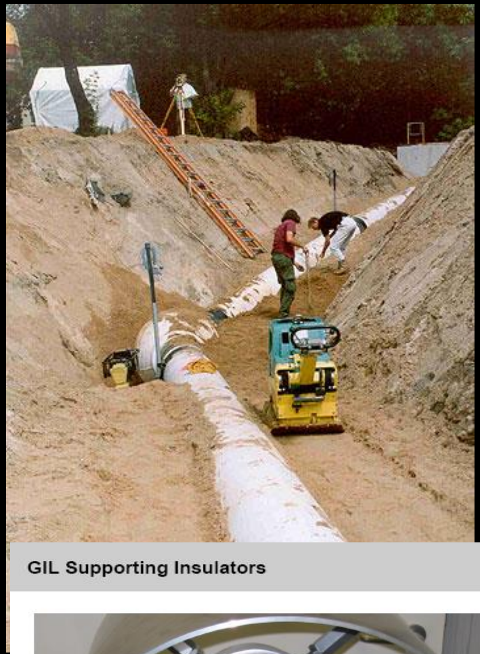
INFLUENCE/parameter	Electric field	Magnetic field	Radio interference	Noise
Approaching phases (Compacting)	SMALLER	SMALLER	A LITTLE LARGER	LARGER
Raising the conductor above the ground	SMALLER	SMALLER	A LITTLE SMALLER	A LITTLE SMALLER
Increasing the number of conductors in a bundle (at same cross-section)	LARGER	EQUAL	SMALLER	SMALLER
Increasing the distance between conductors in a bundle	A LITTLE LARGER	EQUAL	A LITTLE LARGER	A LITTLE LARGER
Increase the phase conductor cross-section	A LITTLE LARGER	EQUAL	A LITTLE SMALLER	A LITTLE SMALLER

6. What are alternatives?

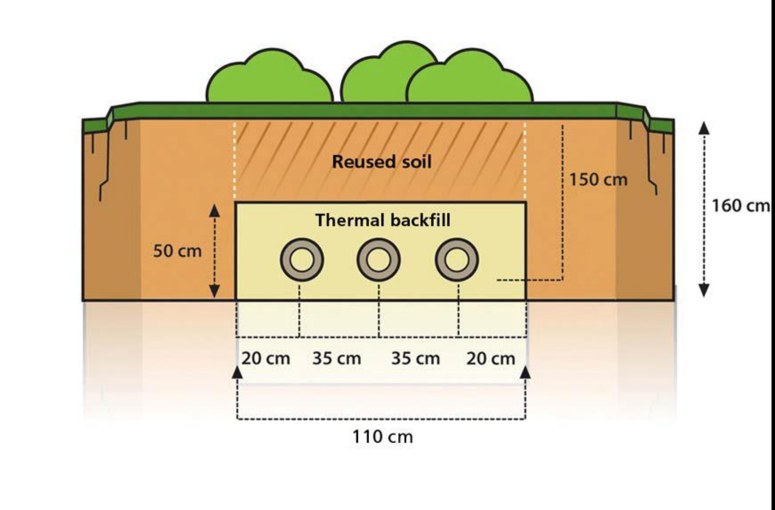
A. New technologies of underground transmission (cables, GIL)
B. DC interconnections/HVDC super grid
C. New types of conductors for OHLs
D. New pillar and tool shapes
E. Setting new dynamic ratings of OHLs
F. Cryogenic technologies (HTS)
G. Hybrid AC/DC interconnections
H. EMC management
I. Management of instability of long transformations of synchronous systems

A. New technologies of underground transmission (cables, GIL)

GIL (Gas Insulated Lines)



KABLI



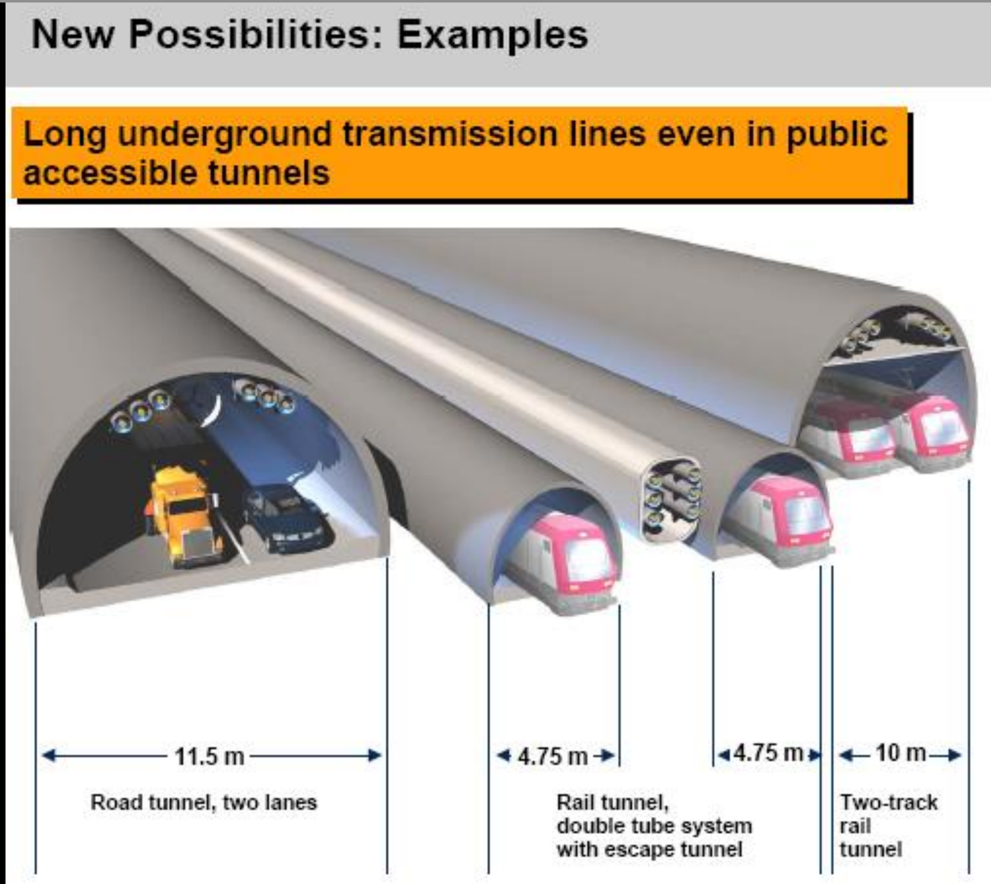
More recent practice allows the construction of partial cable connections:
DV + CABLE.

There are several examples worldwide (FR, NL, SE) that companies have changed thousands of km of overhead lines at 20 kV with cables (20 kV) due to increasingly severe weather conditions. In doing so, the peasants protested, they wanted the OHLs which they can see, unlike underground cables, which possibly hit them with plows.

At 400 kV, the underground network is very expensive (7-10x and more) and causes many problems in system operation due to reactive power and, consequently, voltage instability.

GIL technology

This technology is only suitable for very large required power transfers of the order above 2000 MW per system. The cost per transmitted power is greater than cable systems. There are some examples of the use of this technology in the world.

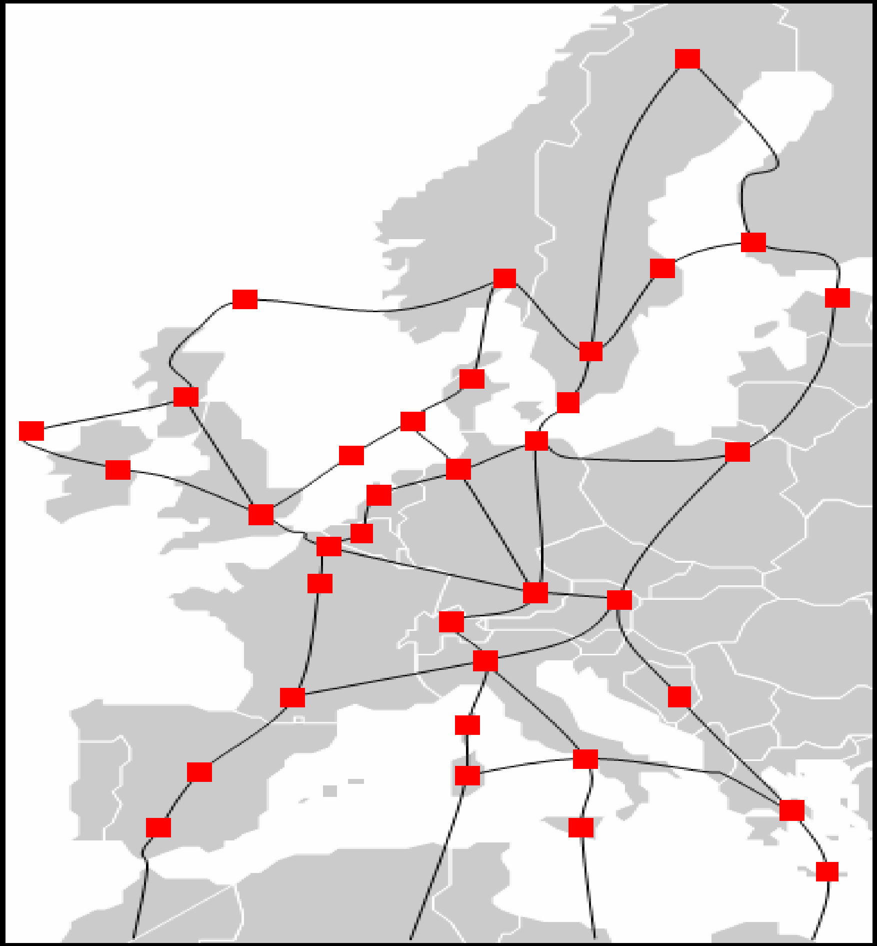


Technical advantages:

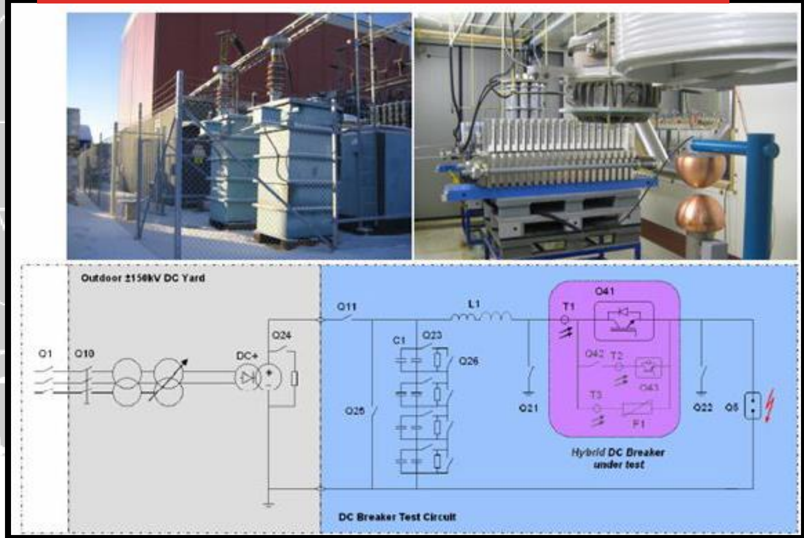
1. Joule losses are relatively small,
2. Dielectric losses are negligible,
3. Relatively low capacitance per unit length,
4. Reactive power compensation is not required even on lengths exceeding 100 km,
5. It can be buried directly in the ground or installed in an existing tunnel…
6. Technically, it resembles an overhead line.

B. DC interconnection /HVDC super grid

Here is an idea for a new large-capacity European HVDC network (SUPERGRID) to be installed beneath existing motorways.

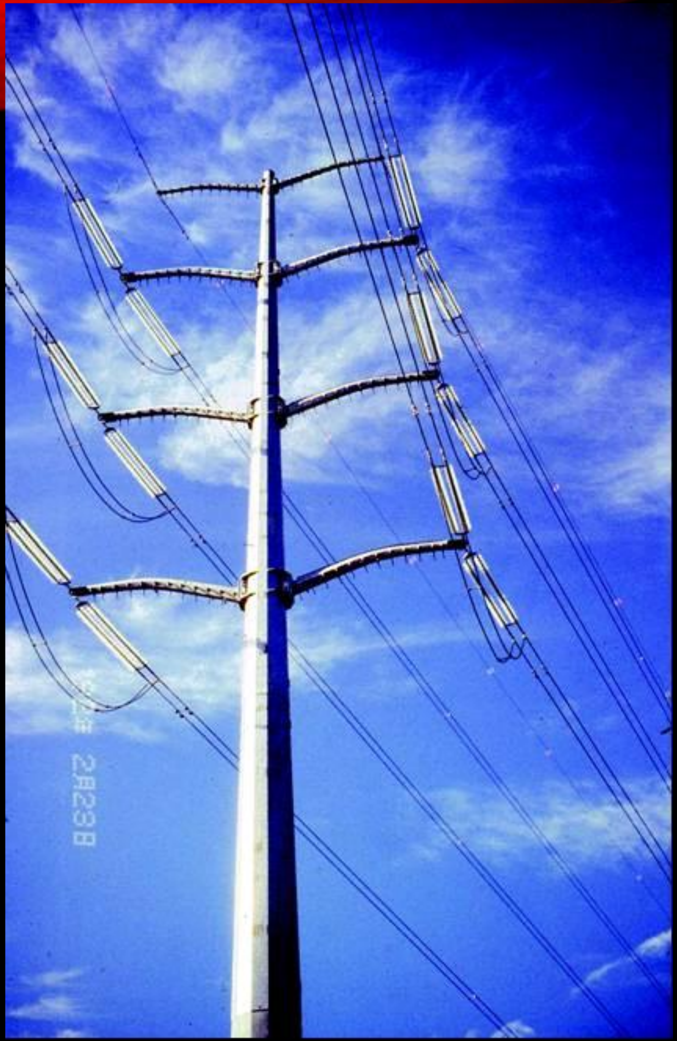


This is the first in the world history DC circuit breaker – presented at CIGRE session in Paris.



HVDC OHL tower

D. New tower



This is what looks like a modern 400 kV transmission line

C. New types of conductors for OHLs

Conductors with non-metallic (ceramic) materials for cores

New materials for conductors capable of electric current up to 250 C with low temperature expansion.

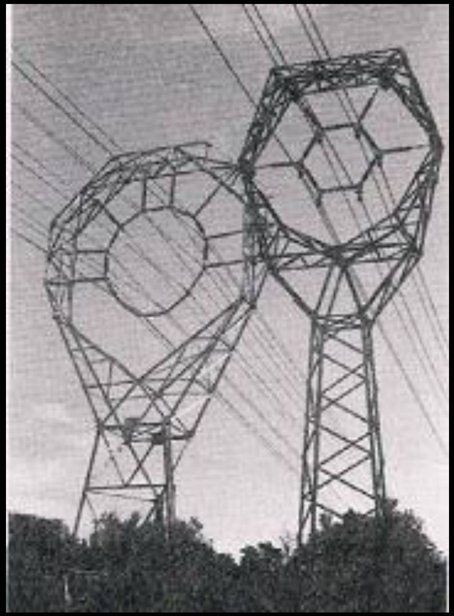
Comparison between new and old OHL

ENVIRONMENTAL IMPACTS OF TRANSMISSION LINES

Solutions to reduce space use

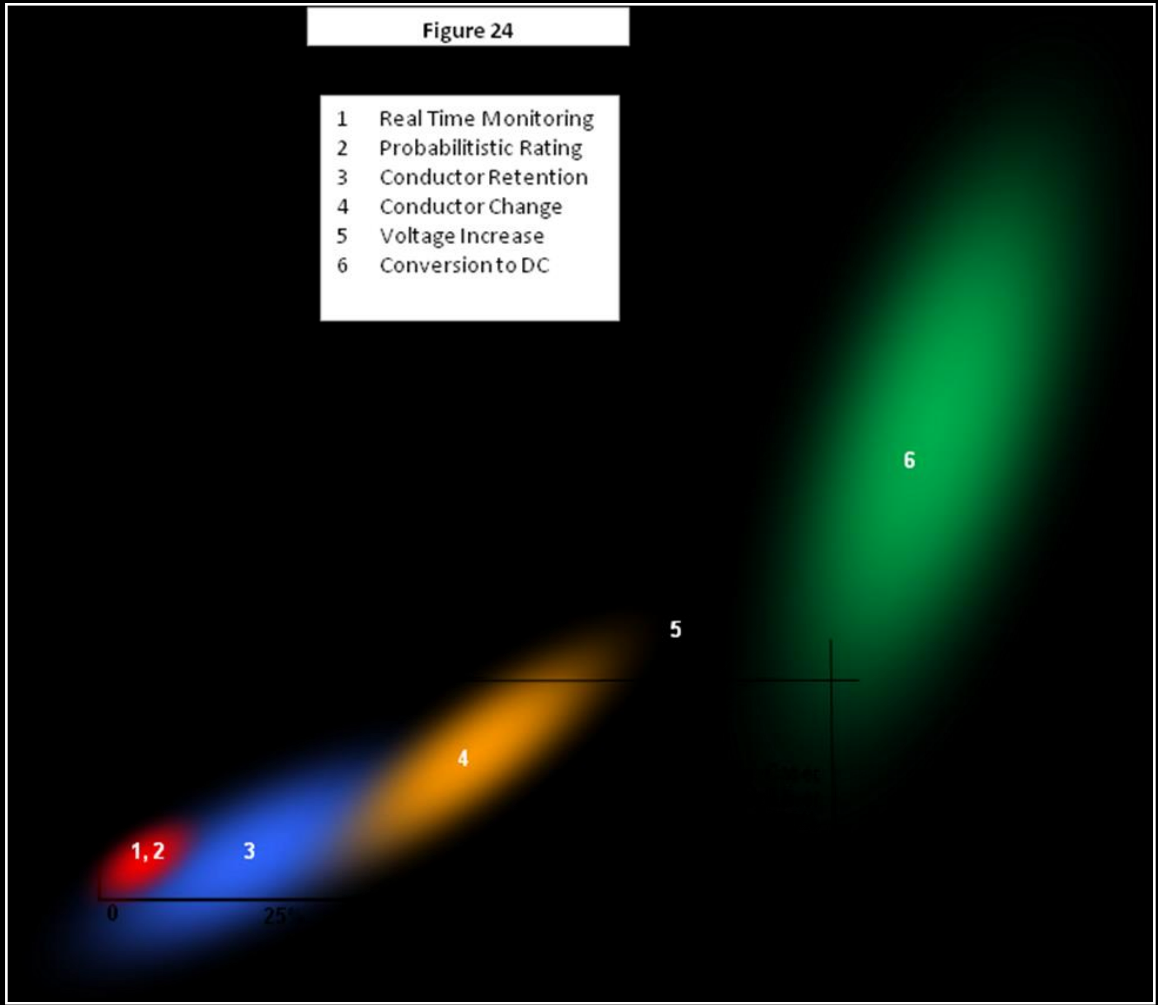
a. Current approach,
b. Voltage approach,
c. Conversion AC v DC
d. Hybrid approach

<u>Current approach</u> enables solutions with:
- Introduce of Dynamic monitoring's
- Replacing conductors or new HTLS



12 and 6-phase138kV OHL

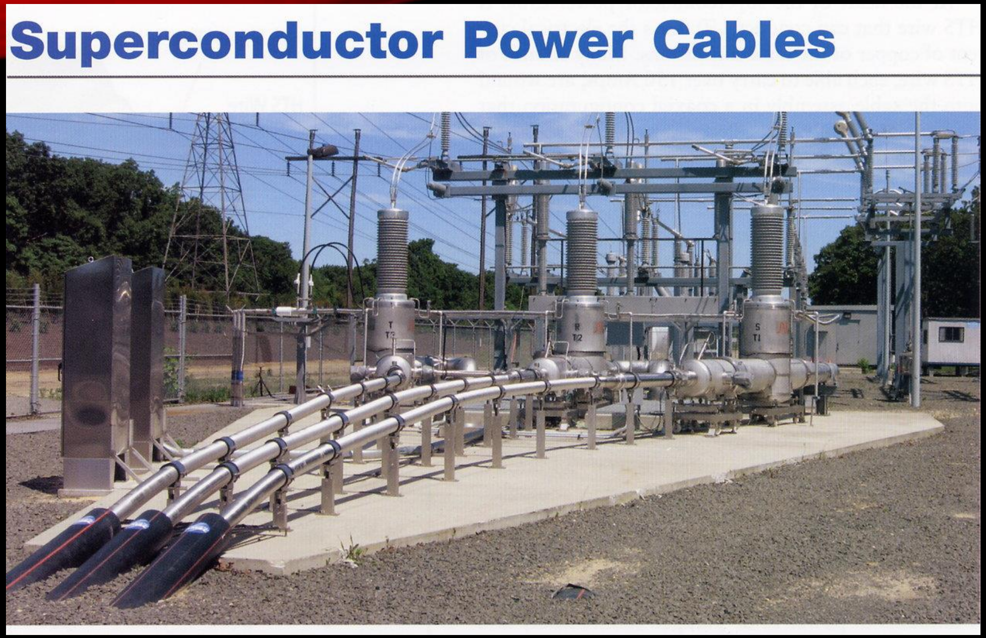
Transmission capacity enhancement technologies in the corridor and cost dependency



AC to DC conversion technology allows for maximum performance boosting effects and also presents the technology with the highest cost.

SOURCE: Increasing Capacity of Overhead Transmission Lines , Needs and Solutions , Študija CIGRE, Ref. 425, Pariz, 2010.

F. Cryogenic technologies (HTS)



Superconducting cables are a option of the future transmission. Currently, their price is about 40 times higher compared to overhead 400 kV transmission lines.

Technical advantages:

a) high capacity of electric current or transmission of electrical power (up to 30 times more current per mm²),
b) relatively small conductor dimensions,
c) small losses (ca. 1% vs. conventional cables),
d) do not cause thermal pollution in the environment,
e) They have excellent electromagnetic protection and do not radiate to the surrounding area.

Technology of the future:

3 commercial projects: in the USA, in Germany at distribution level German pilot project for 10 kV instead of 110 kV (in Essen) – they said cheaper solution ????.

COMPARISON OF THE PROS AND CONS OF ALTERNATIVE OPTIONS

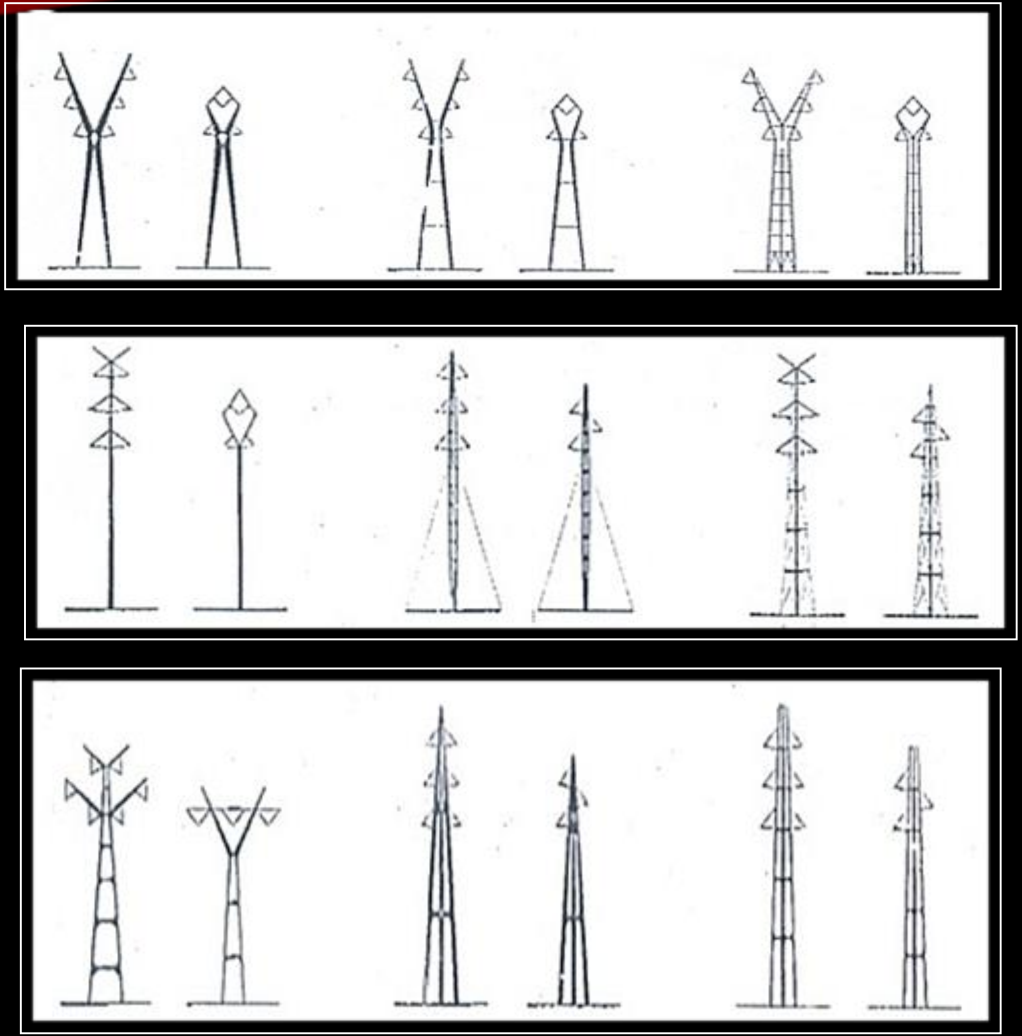
TECHNICAL CHARACTERISTICS	AC OHL	AC Cable	AC GIL	HTS	DC OHL
Complexity of construction	**	***	****	***** (5)	***
Performance and flexibility	***** (5)	****	****	****	***
Reliability and availability	***	****	****	-	****
Inductance	***	**	*	-	-
Capacitance	**	***** (5)	***	**	***
Loss	***	**	*	*	**
ENVIRONMENTAL IMPACTS					
Visual impact	***** (5)	-	-	-	***
Environmental pollution	*	*	**	**	*
Electrical radiation	****	-	-	-	**
Magnetic radiation	****	***	-	-	*
COSTS					
investment	***	****	***** (5)	***** (5)	****
Maintenance	***	*	**	*	***
Operation (cost of losses)	***	**	*	*	**

Technical / Economical comparison for 400 kV

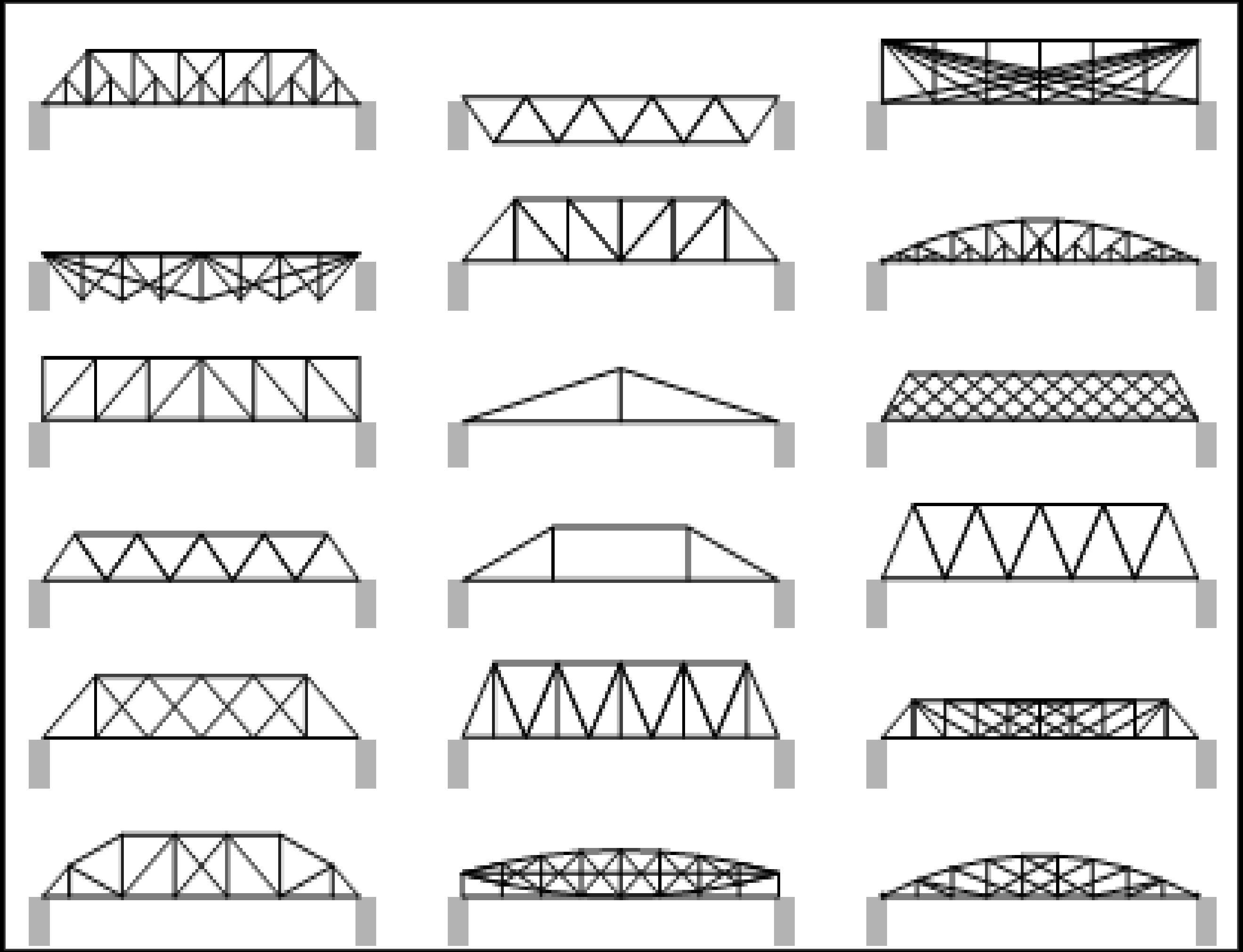
	GIL	OHL	XLPE CABLE (2 per phase)
Nominal current (A)	3000	3000	3000
Rated transmission (MVA)	2078	2000	2000
Losses at 3000 A (Wm^{-1})	180	540	166
Dielectric losses (Wm^{-1})	-	2.4	15
All losses (Wm^{-1})	180	542.4	181
AC resistance ($\mu\Omega m^{-1}$)	6.7	20	6
Inductance (nHm^{-1})	162	892	189
Capacitance (pFm^{-1})	68.6	13	426
Surge impedance (Ω)	48.6	263	21
Characteristic power (MW	3292	608	7619
Economical comparison	20	1	10

What about Aesthetic influences ?

What is difference between OHL towers and bridges ?



TOWERS



BRIDGES

What is difference between OHL towers and bridges ?



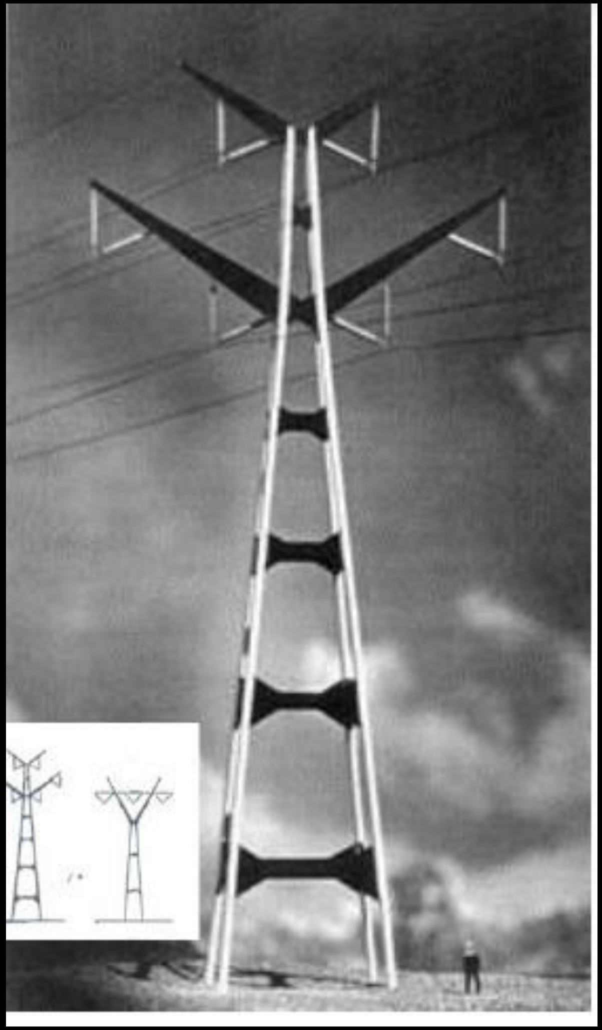


TOWERS




BRIDGES

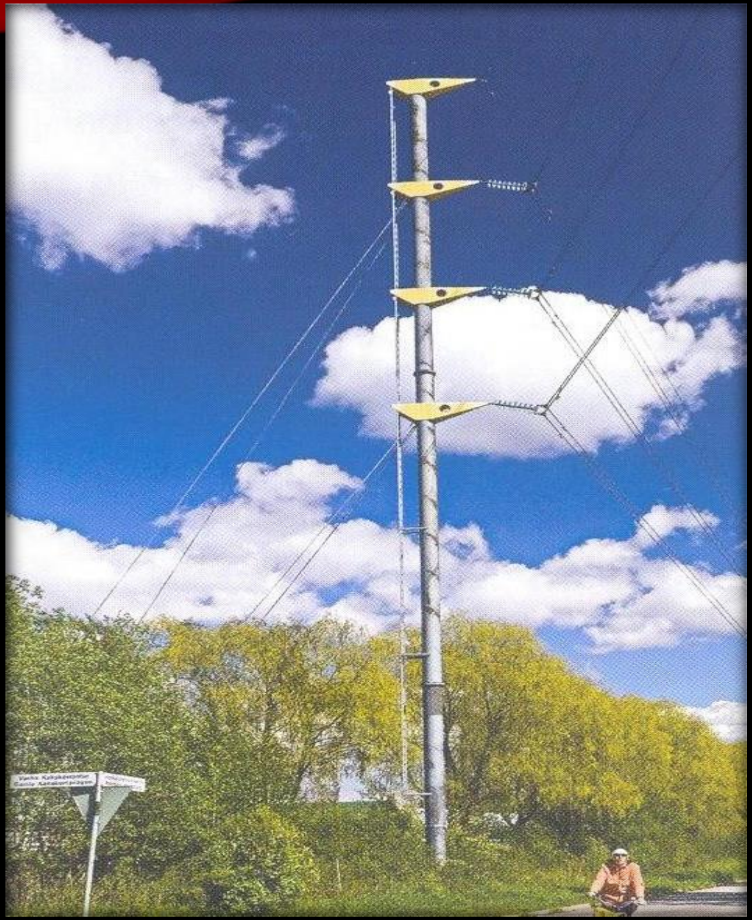
Solutions to improve visual effects



The beginnings of changes of tower designs in 1968 — H. Dreyfuss

First ideas: reduce dimensions, adapt to the environment.

Finland – studies and proposals

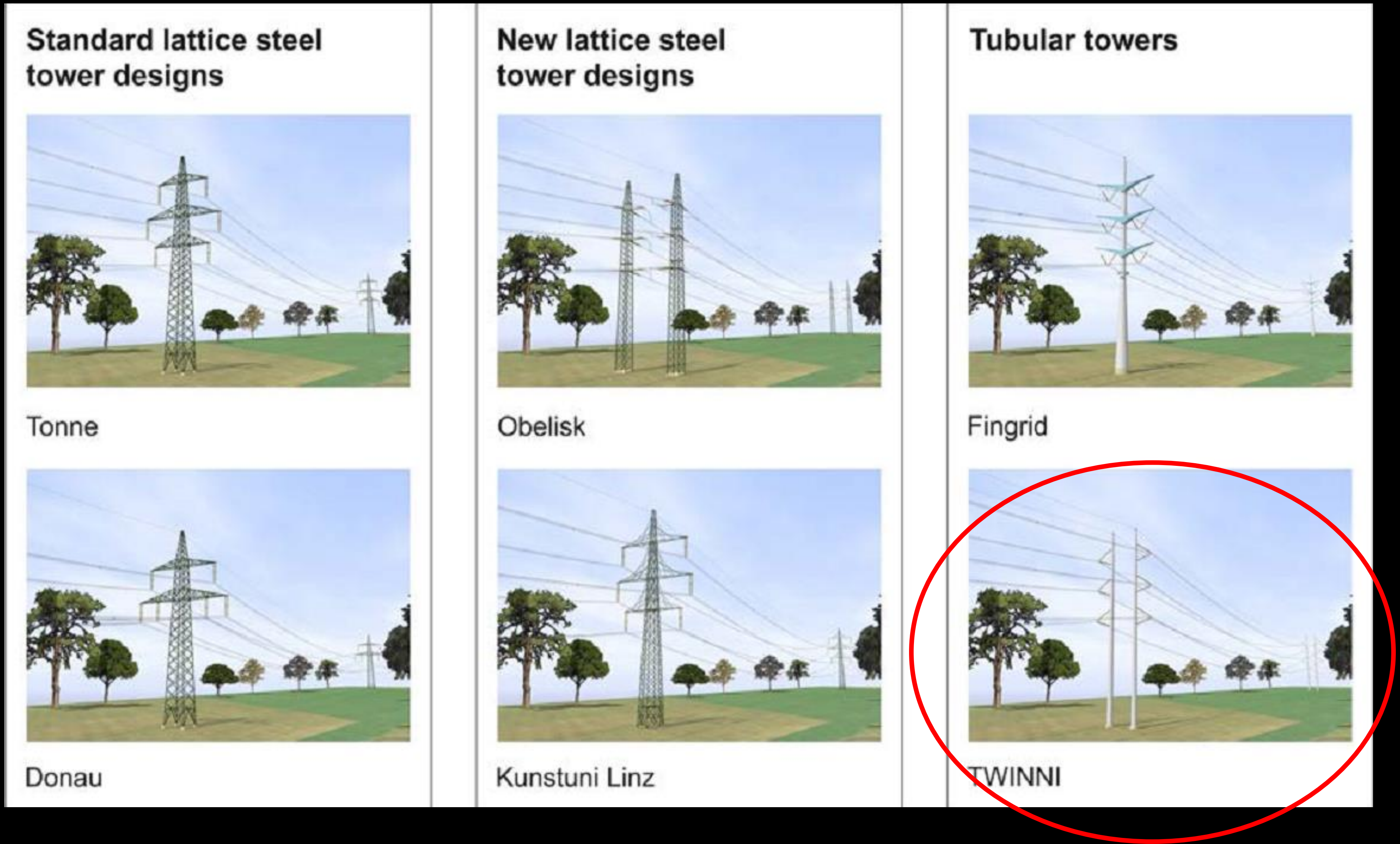


1994: Hiversaloon, Turku. Antti Nurmesniemi

1995: "Sinikurjet", Espoo.Studio Nurmesniemi.

Many European companies, in cooperation with architects, have started designing new images of transmission line pillars that would be more friendly to their surroundings.

AUSTRIA – study for new design of 400 kV OHLs



French experience and competition

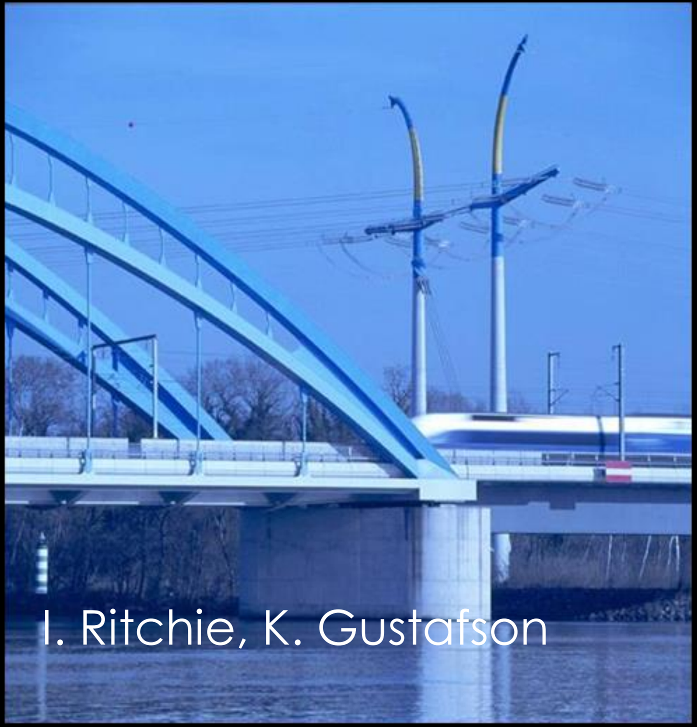
EDF / RTE competition for the most beautiful pillar 400 kV of the new generation: 1994. 21 competitors participated in the competition. For competitors, freedom of creativity was opened, except for safety distances, phase arrangement, and the like.

Marc MIMRAM

Pillar “ROSEAU”

WINNERS

It was a competition of architects and designers.



I. Ritchie, K. Gustafson

Pillar “FOUGERE”

Island : An example of a study of the pillars "The walk of giants"

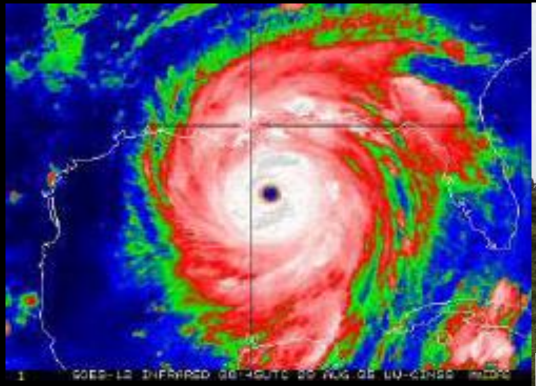
Finland –proposal for the new pillar

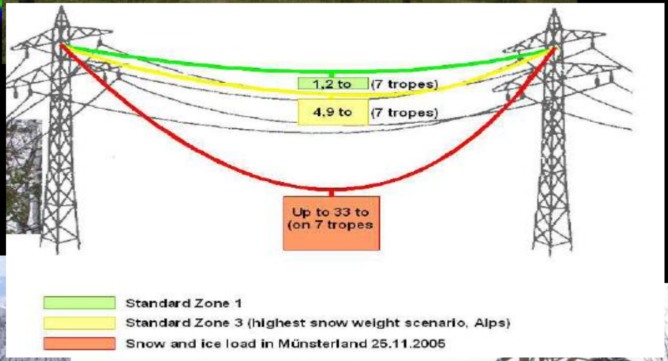
1995: Virkkala. B. Selenius

1996: Tuusula. IVO Power Engineering.

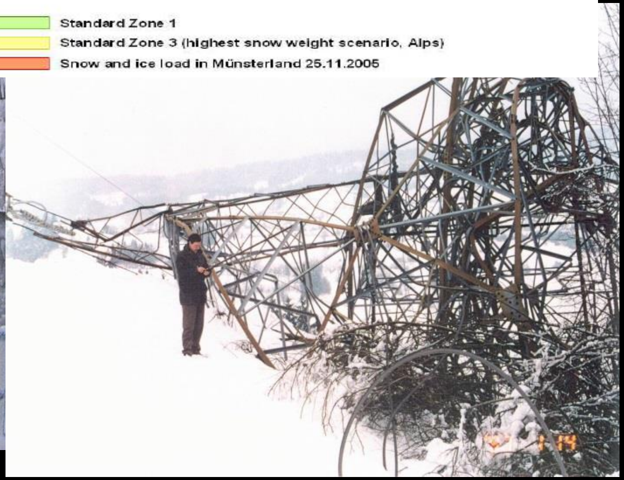
How to reduce the effects of ice disasters, storms

SLOVENIJA 2014





5.11.1980 – Tatre (Brkini)
5.01.1997 – Unec
31.01.-02.02.2014 - Slovenija



How to reduce the effects of ice disasters, storms

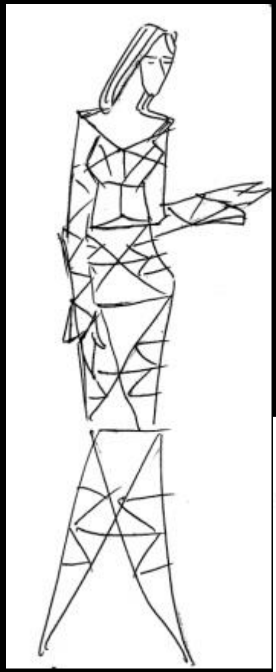
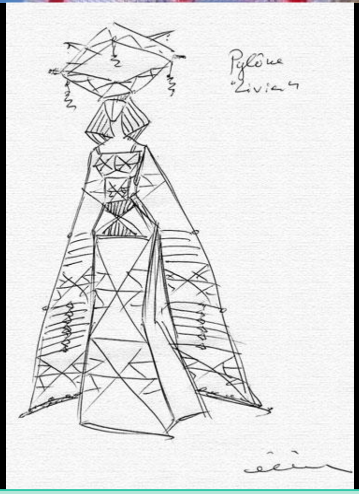
Measures / Technological solutions:

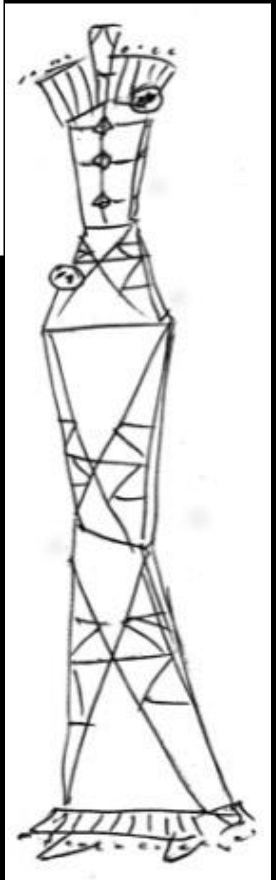
- New design standards, EN 50341-1:2012,
- New wind and ice weather maps,
- Reliability classes of each OHL,
- New network planning criteria,
- Development of new materials,
- Introduction of an icing control system,
- Increase in the number of meteorological stations in the network,
- Introduction of de-icing methods,
- Increasing network redundancy,
- Greater diversification of resources in system development,
- In forest areas, network cabling up to 110 kV,
- New forms of pillars resistant to icing,
- Mandatory introduction of risk methods for OHLs,
- Introduction of an independent communication system,
- Introduction of crew training for emergencies.

Towers as art





Bulgarian artist's ideas for new images of transmission line pillars.

OHL'S ARE NOT UGLY, FOR A SUSTAINABLE FUTURE WE NEED MORE SMART ELECTRICITY TRANSMISSION SOLUTIONS FOR A MORE AFFORDABLE ELECTRICITY PRICE.

HERE, CIGRE'S ROLE IS OUTSTANDING**.**

Thanks for attention