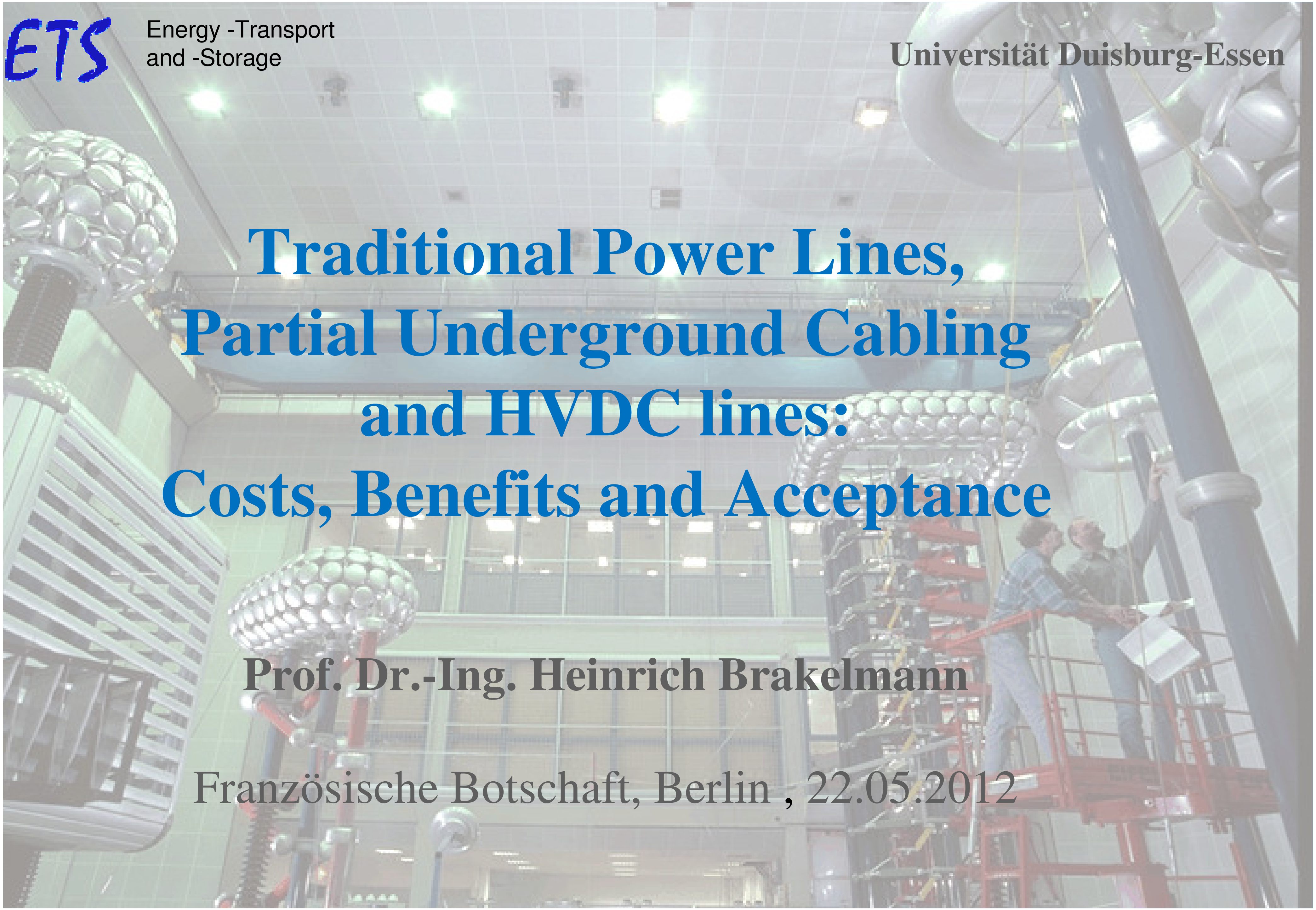
ETS Energy -Transport and -Storage

Universität Duisburg-Essen



Traditional Power Lines, Partial Underground Cabling and HVDC lines: Costs, Benefits and Acceptance

Prof. Dr.-Ing. Heinrich Brakelmann

Französische Botschaft, Berlin , 22.05.2012

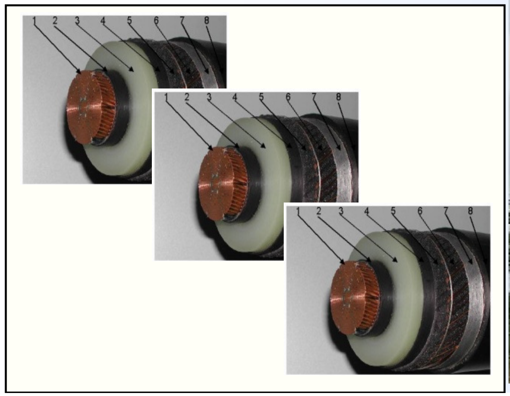
University Duisburg-Essen

necessary grid-extension:

- overhead lines and/or underground cables ?
- HVAC or HVDC ?
- HVDC classic or VSC
- HVAC 50 Hz or 16,7 Hz ?

DENA I (February 2005):

850 km new 380-kV-lines up to 2015



3phase-cable technology:

- new possibilities
- new materials
- new tunneling technologies
- marginal soil heating
- monitoring
- cooling
- magnetic shieldings

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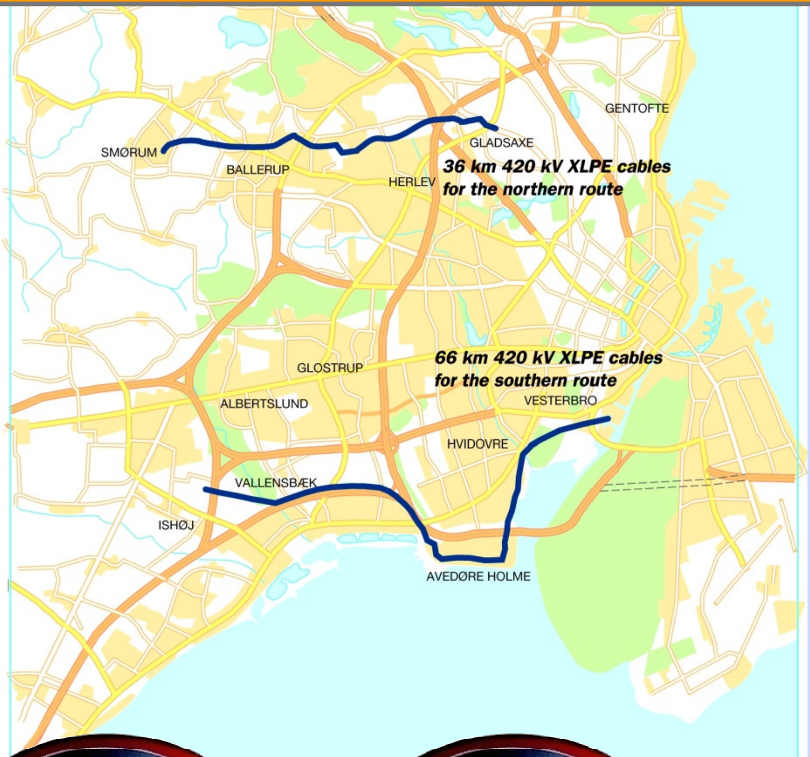
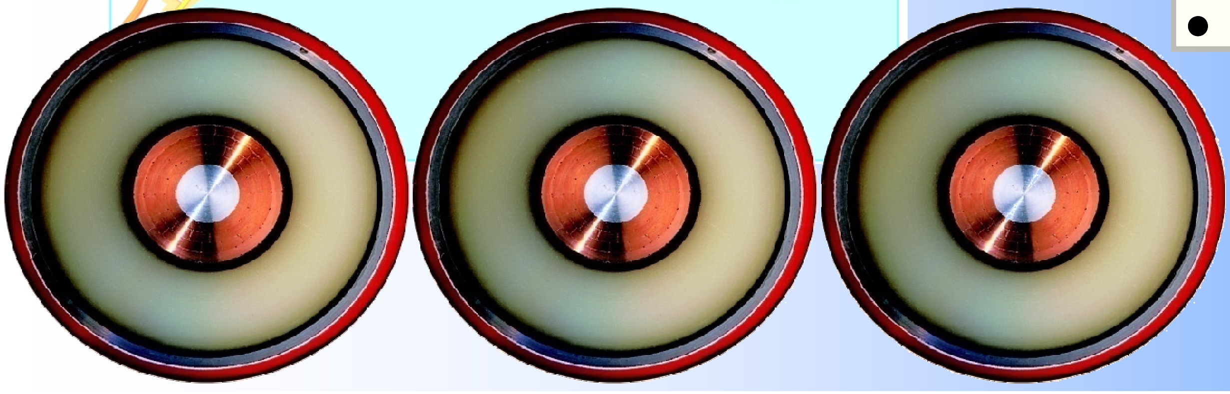
400 kV XLPE Cable Route Copenhagen





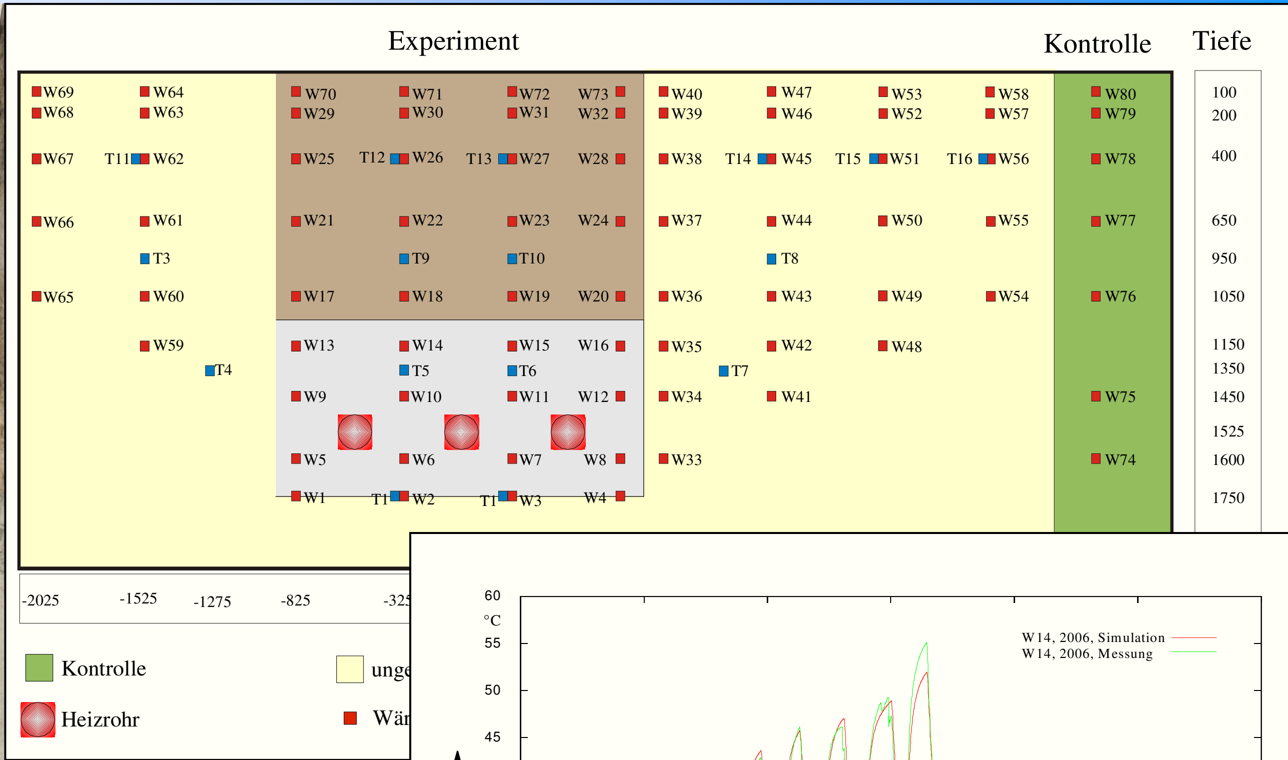
<u>Southern Route (first phase)</u>

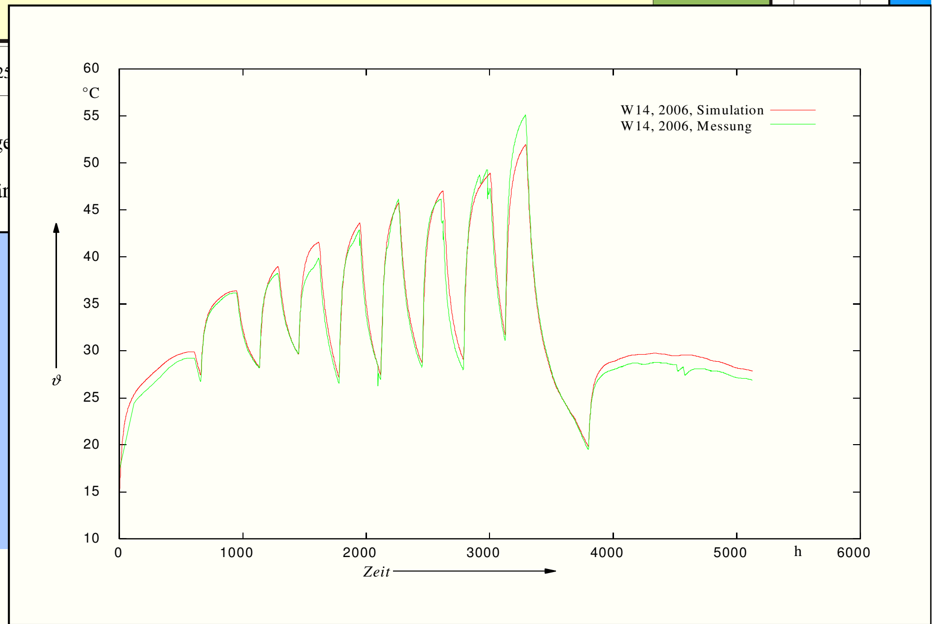
- 22 km route length
- 66 km 400 kV XLPE cable
- 72 prefabricated joints
- 9 GIS sealing ends
- 3 outdoor sealing ends
- in service since Oct. 1997

<u>Northern Route (second phase)</u>

- 12 km route length
- 36 km 400 kV XLPE cable
- 42 prefabricated joints
- 9 GIS sealing ends
- 3 outdoor sealing ends
- in service since Dec. 1999

state of the art:
XLPE-cables up to
$U = 500$ kV



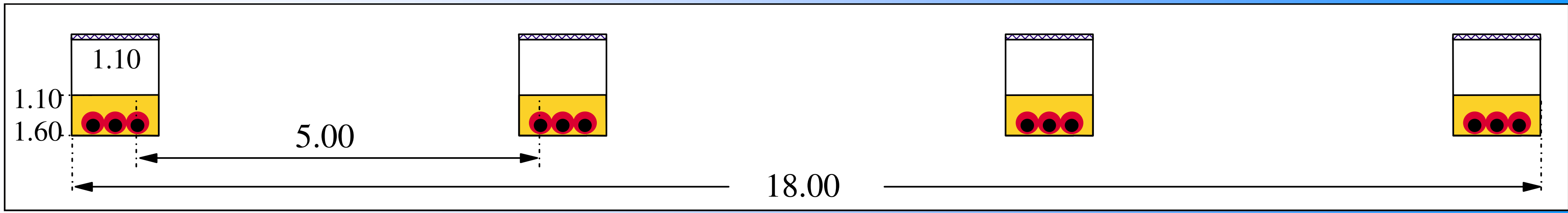


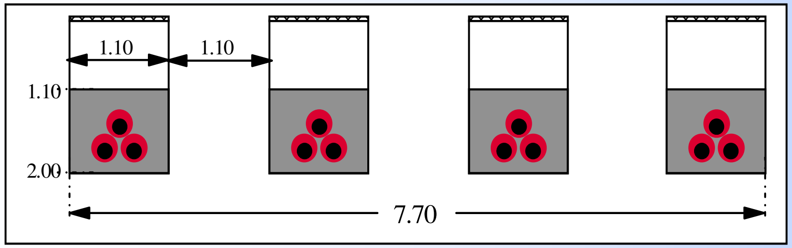
Thermal Impact of Heat-Emitting Power Cables

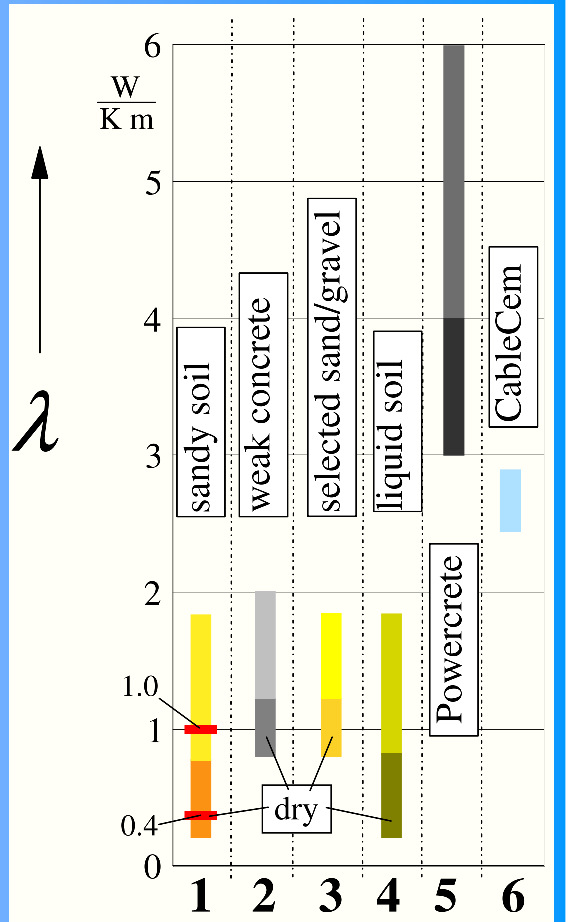
D. Uther
RWE Transportnetz
Strom GmbH,
Dortmund

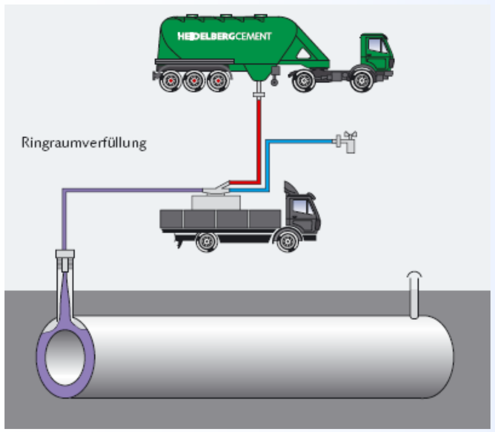
P. Trüby, E. Aldinger
Institut für Bodenkunde und
Waldernährungslehre
Albert-Ludwigs-Universität, Freiburg

H. Brakelmann, J. Stammen
Energietransport und -Speicherung
Universität Duisburg-Essen





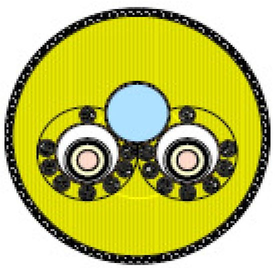




new materials for thermal stabilisation

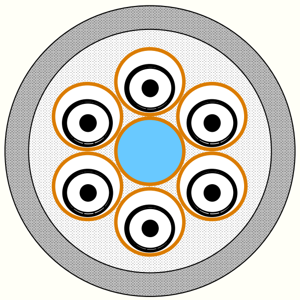
PowerTubes

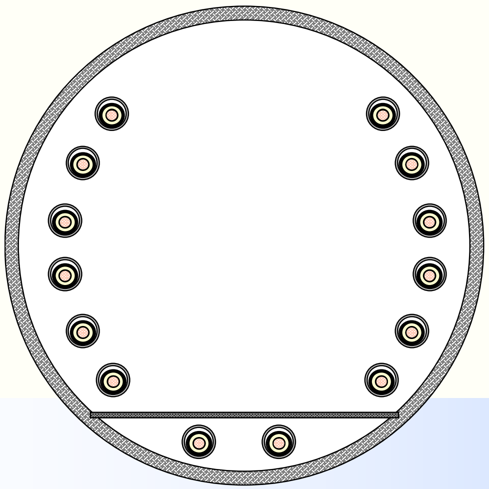
Low-Impact Cables with Minimal Demand for Trench Space and with Maximum Reliability



Quellen: Uni Duisburg, nkt-cables, Prof. Stein&Partner, Dupré-Bau

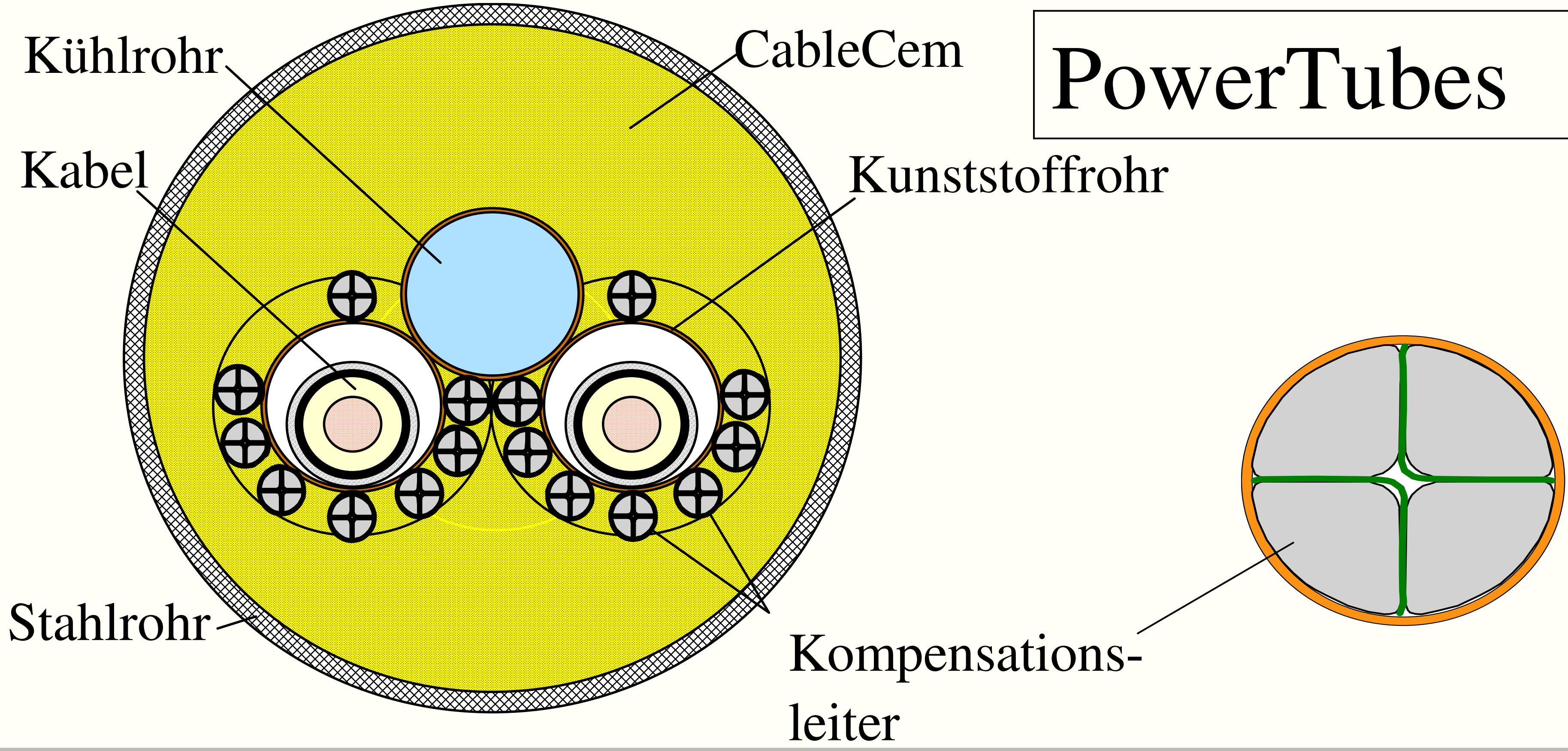
PowerTubes: Innovative Cable– and Installation Systems

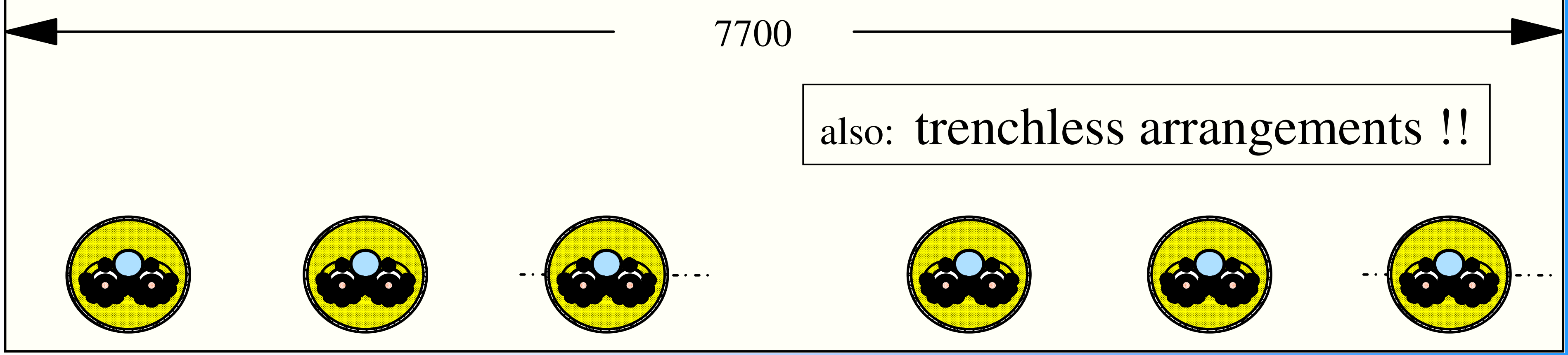




- trenchless
- use of existing infrastructures
- low impact
- reliable
- safe in operation and service
- high transmission power

PowerTubes





also: trenchless arrangements !!

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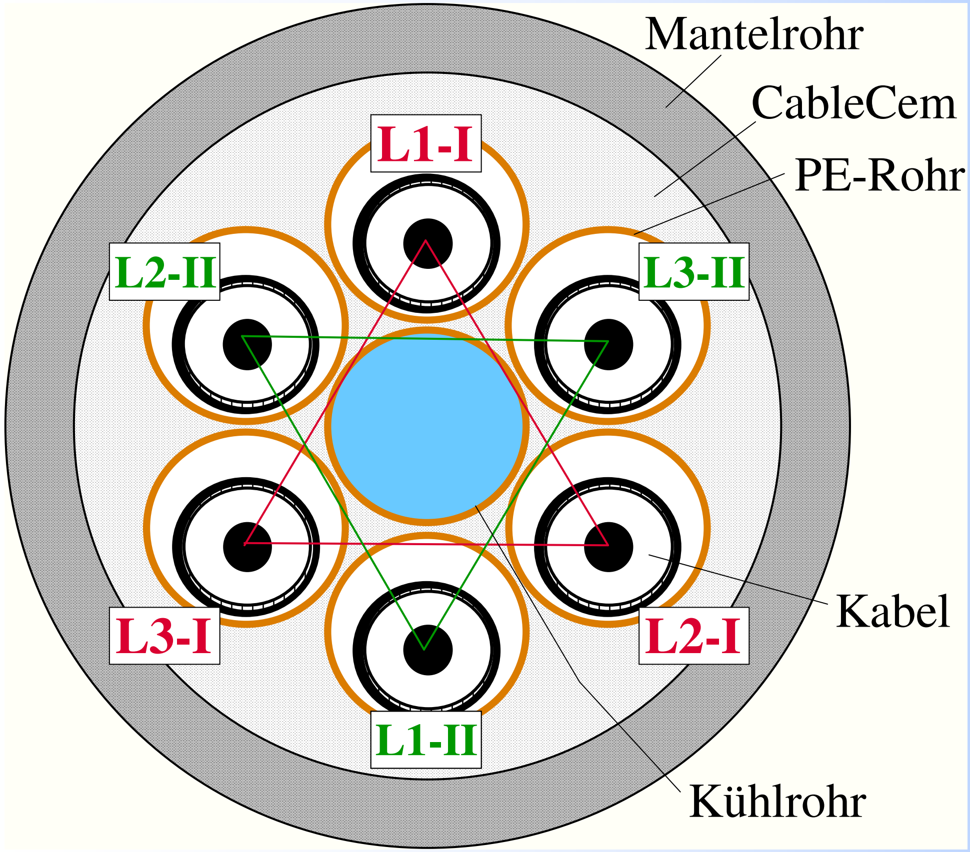
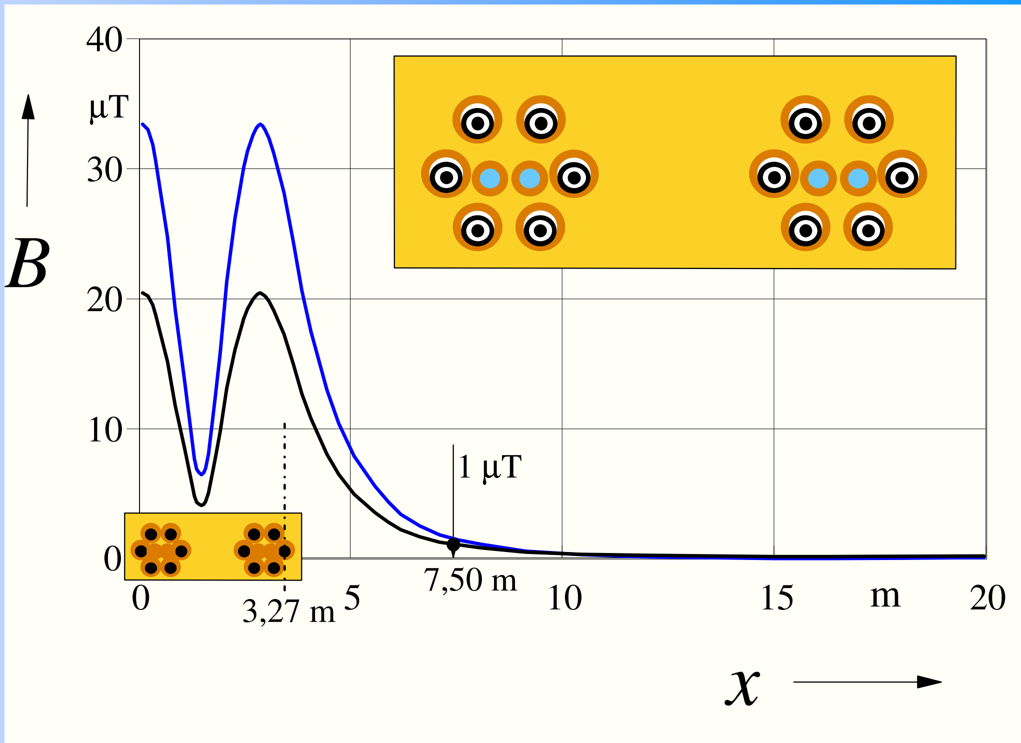
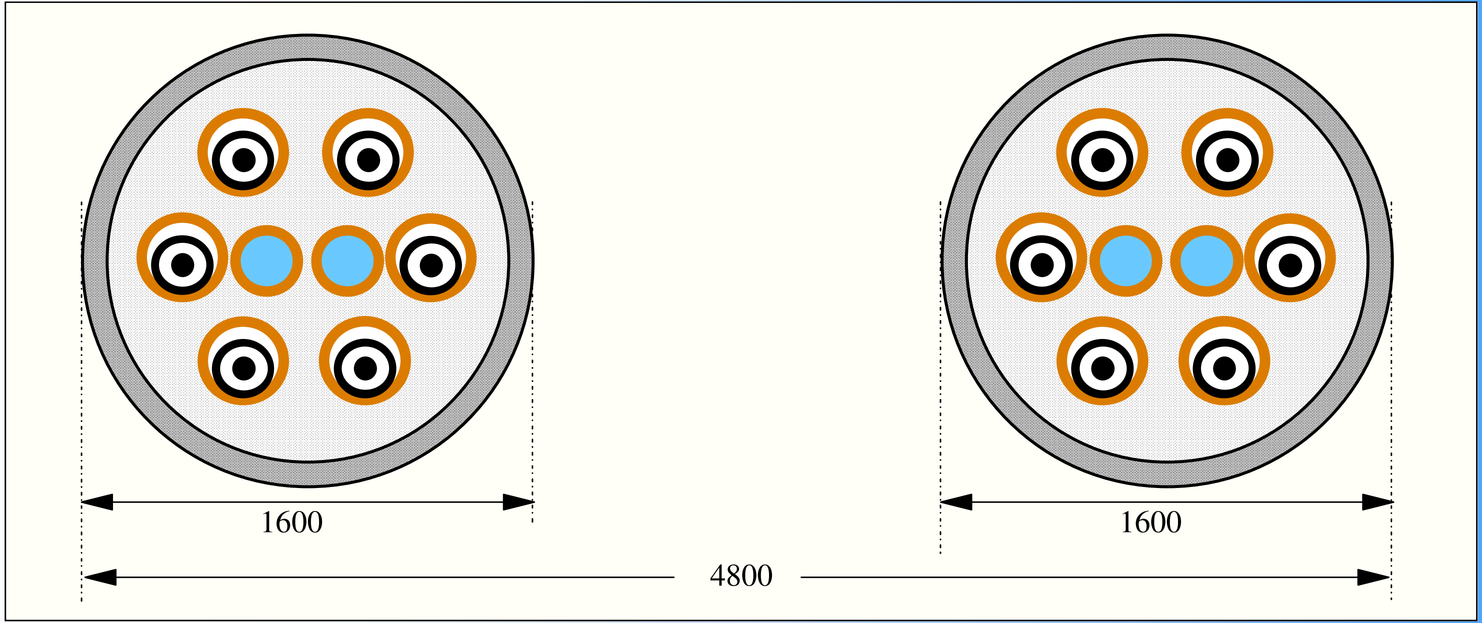


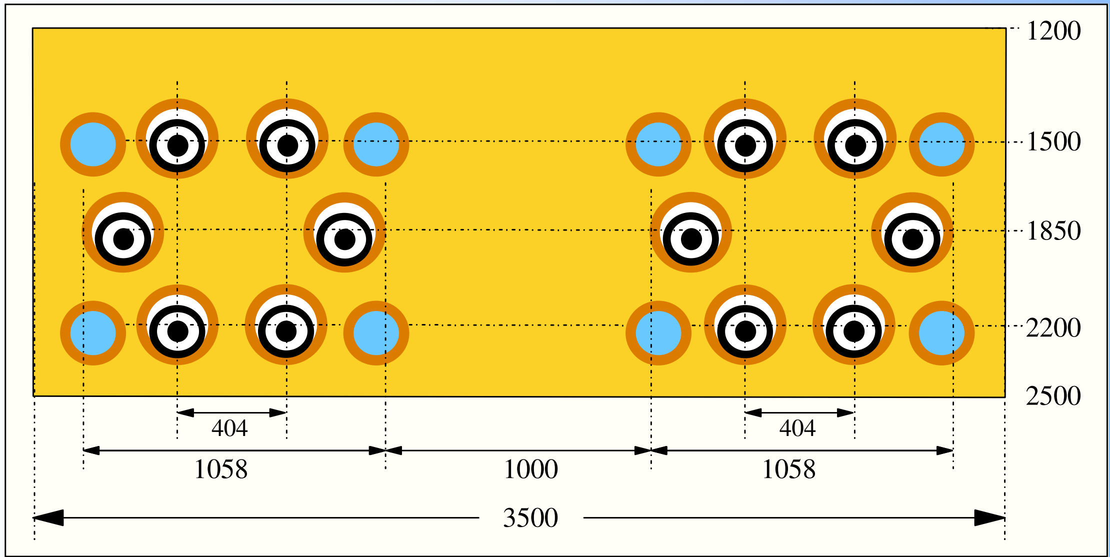
phase-splitting

(e.g. 1 µT in 4m distance)



ETS



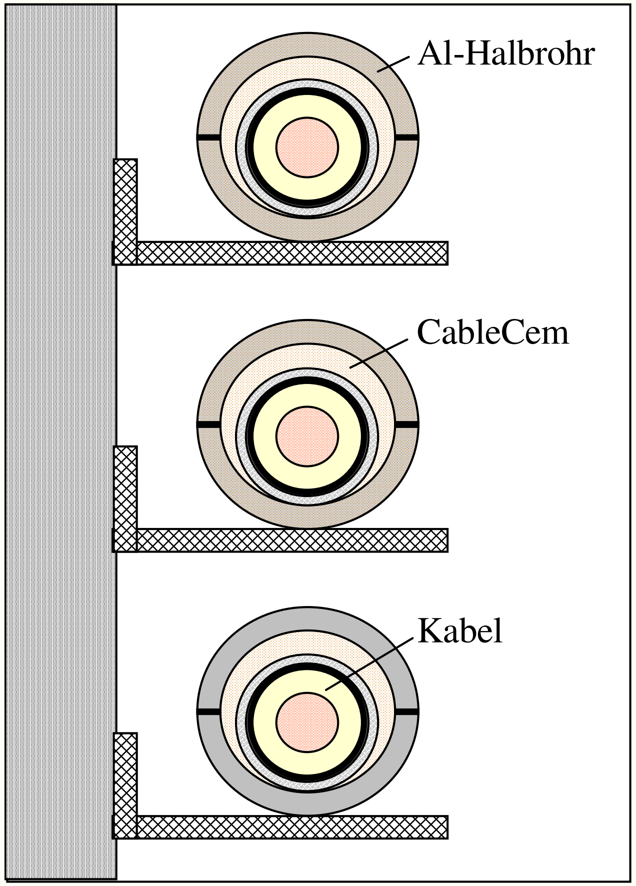


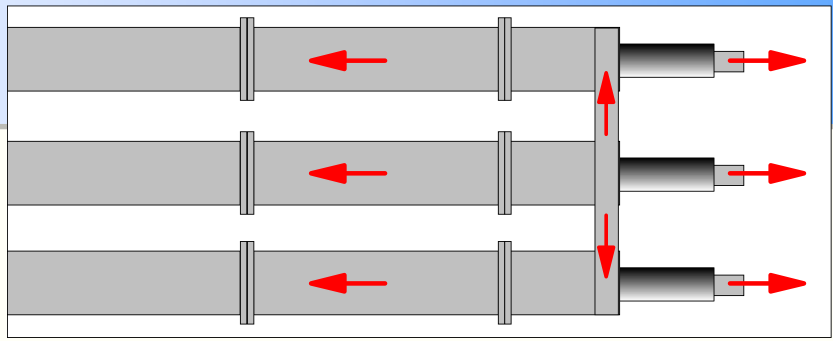
phase-splitting

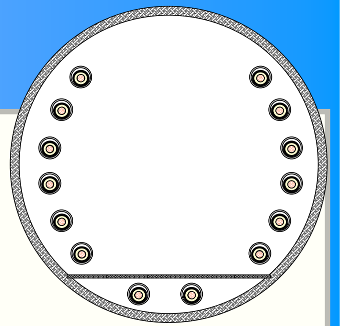
PowerTubes

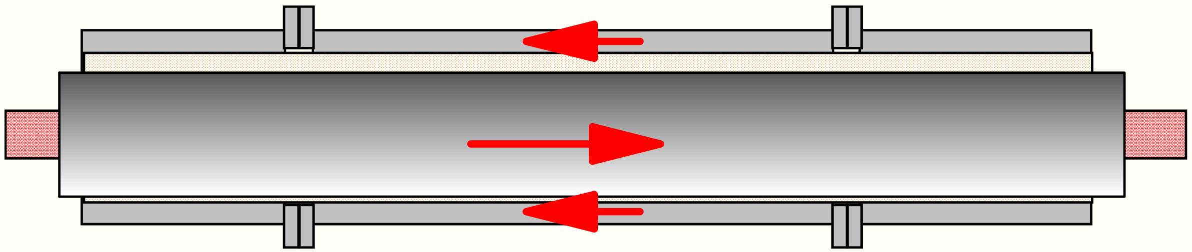
Stromtunnel in Berlin DN 3000 (6 x 380 kV)

Questions for tunnels:
- working under voltage?
- magnetic stationary field
- magnetic field during faults
- forces during faults
- impact of electric arc









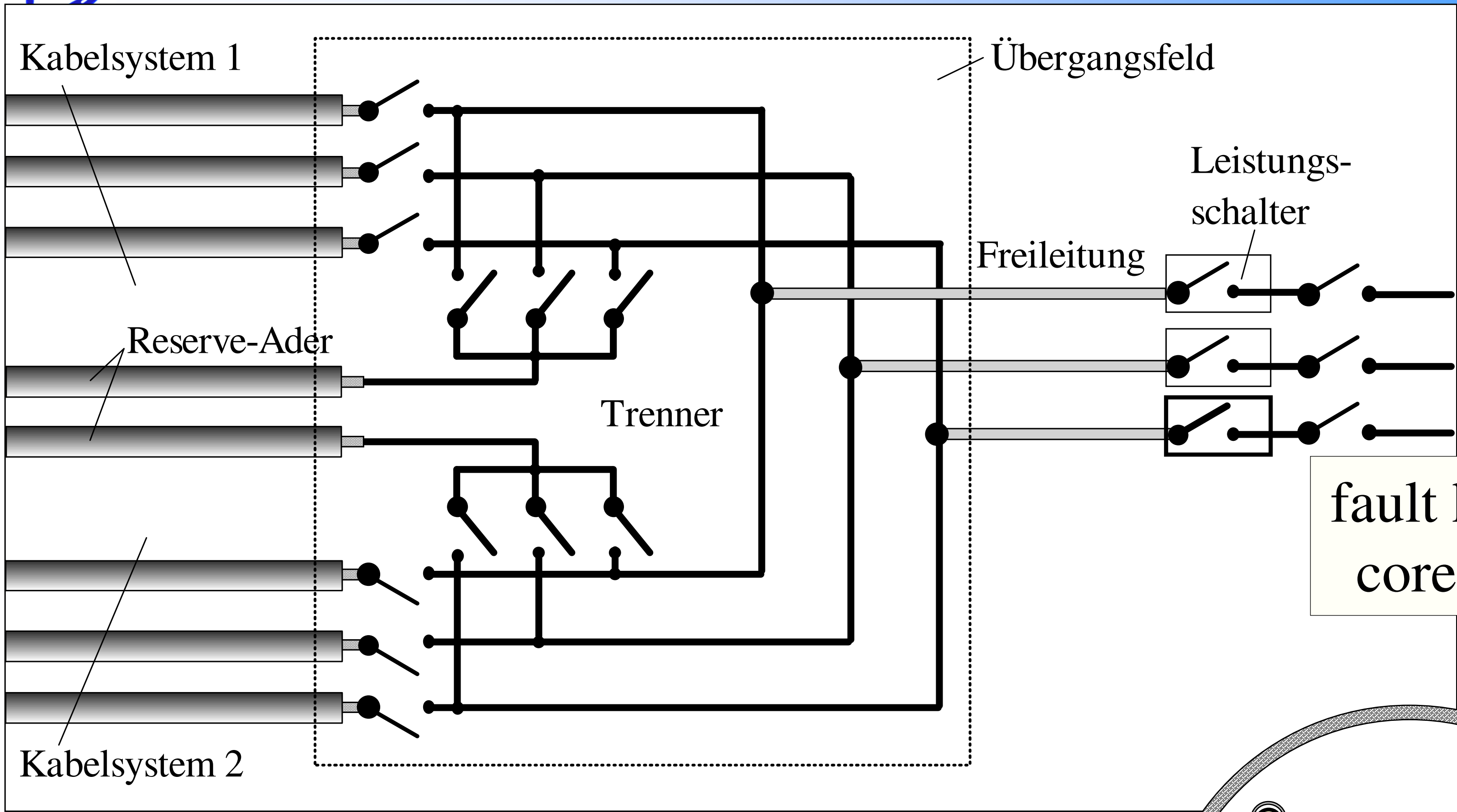
No cross-bonding of the copper-screens

marginal magnetic field

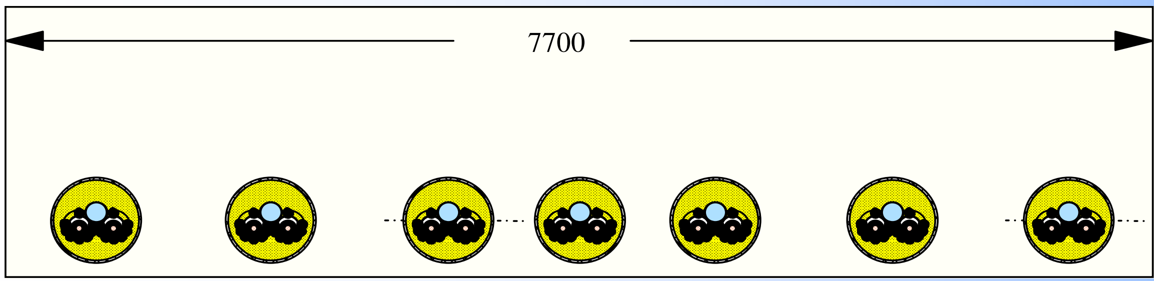
no blast wave

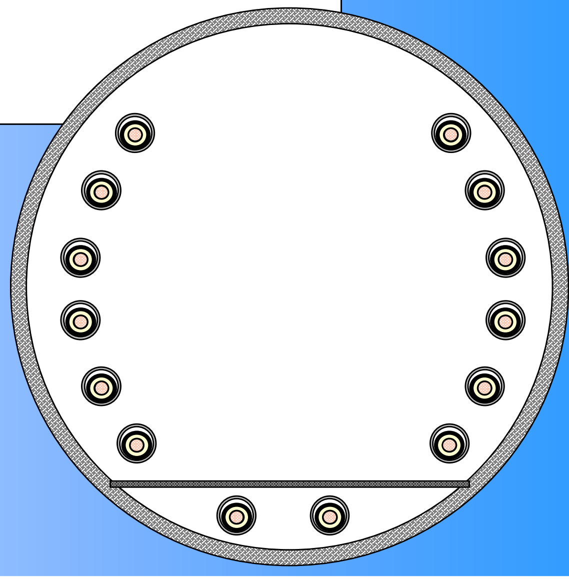
marginal fault forces

coaxial operation/el. decoupling

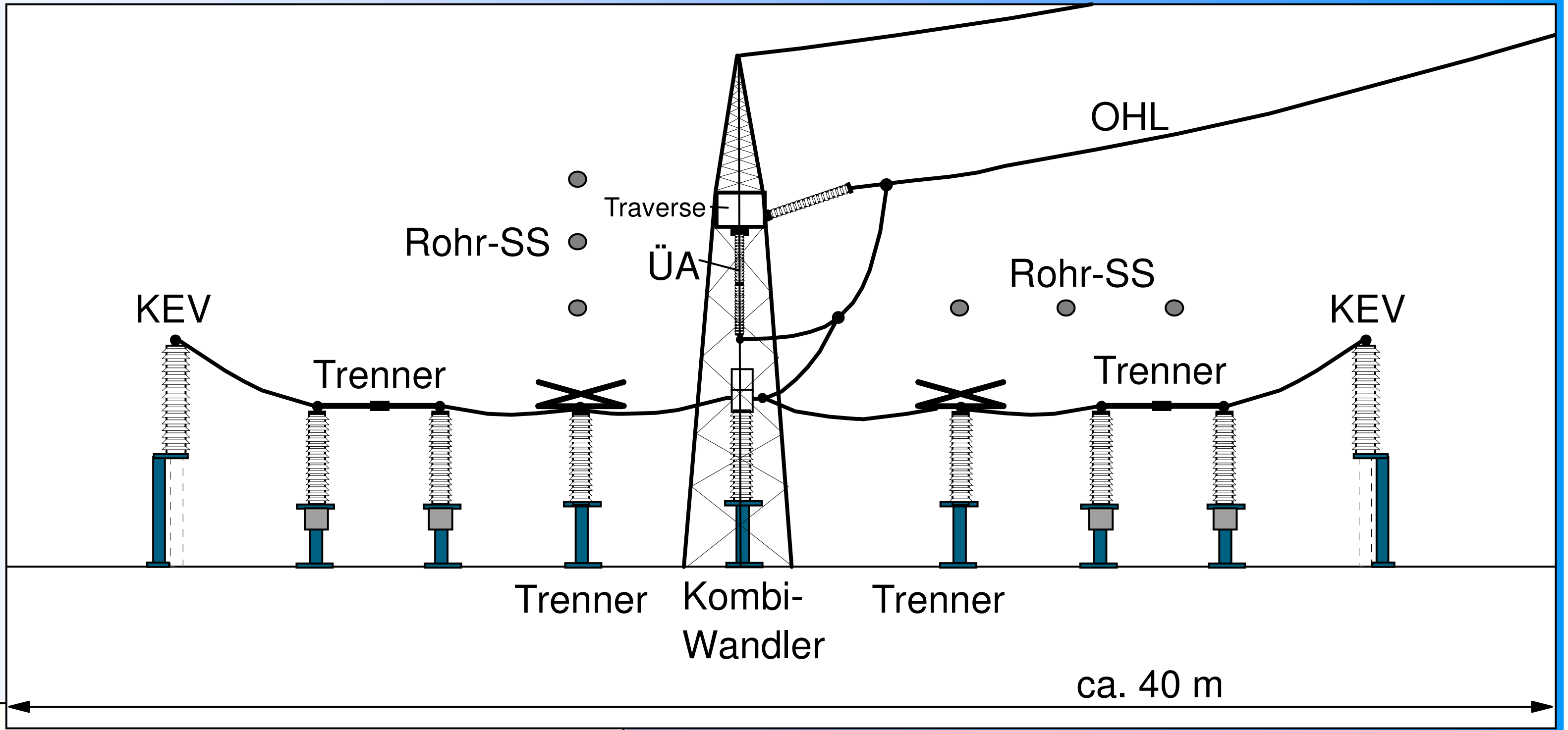


fault handling with core-redundancy

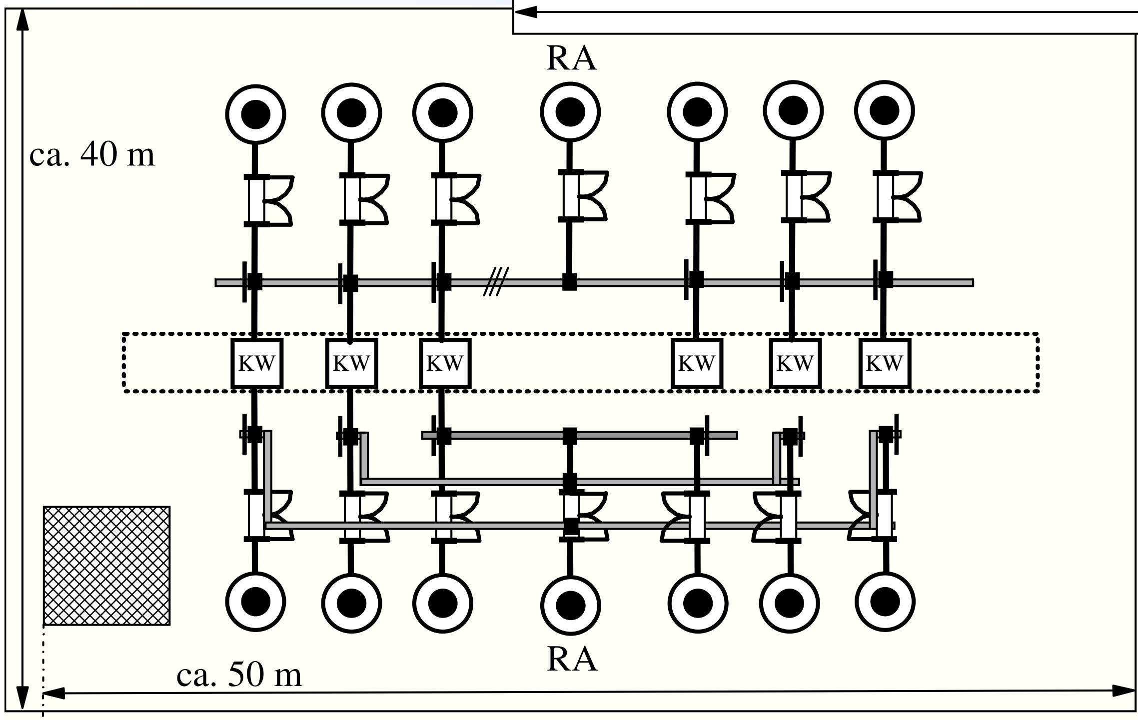




ETS



OHL
Traverse
Rohr-SS
ÜA
Rohr-SS
KEV
KEV
Trenner
Trenner
Trenner
Kombi-
Wandler
Trenner
ca. 40 m



RA
ca. 40 m
KW
KW
KW
KW
KW
KW
RA
ca. 50 m

ETS

Availability with Spare Cores (RA)

n_{Sys}; n_{RA}	r	t_{Umsch}	$t_{(n-1)}$	$t_{(n-2)}$	$t_{(n-3),10km}$
	/(100 S-km*a)	h	h/a	h/(10 km*a)	h/(10 km*a)
Freileitung 2 Systeme	2*0,220	8,0 h	**0,352**	**X** (common mode)	**X**
Kabel 4 Systeme **0 RA**	4*0,145	-	**34,8**	**X**	**X**
Kabel 4 Systeme 1 RA, t_{Rep} = 600 h	4*0,145	**6 h**	**0,348**	**0,853**	**X**
Kabel 4 Systeme 2 RA, t_{Rep} = 600 h	4*0,145	**6 h**	**0,348**	**0,353**	**0,360**
Kabel 4 Systeme 1 RA; t_{Rep} = 600 h	4*0,145	**1 h**	**0,058**	**0,563**	**X**
Kabel 4 Systeme 2 RA; t_{Rep} = 600 h	4*0,145	**1 h**	**0,058**	**0,059**	**0,066**
Kabel 4 Systeme 1 RA; t_{Rep} = 600 h	4*0,145	**5 min**	**0,005**	**0,509**	**X**
Kabel 4 Systeme **2 RA; t_{Rep} = 600 h**	4*0,145	**5 min**	**0,005**	**0,005**	**0,012**

Jährliche Dauer der verletzlichen Phase einer 10 km langen 380-kV-Zwischenverkabelung mit 2 Freileitungssystemen und 4 Kabelsystemen mit n_{RA} (bis zu 2) Reserveadern

actual-values: mittlere Reparaturdauer OHL 8 h, Kabel 600 h; Muffenabstand 1,0 km (nach CIGRE [6]: nur interne Fehler); Parameter: Ausfallrate r; Umschaltdauer t_{Umsch}

constructional realisations

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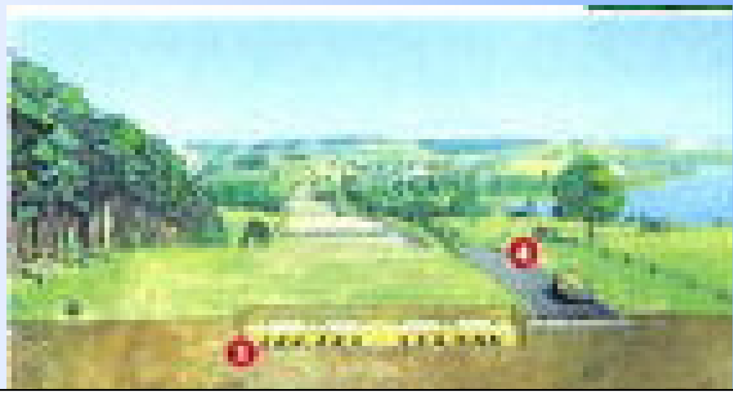
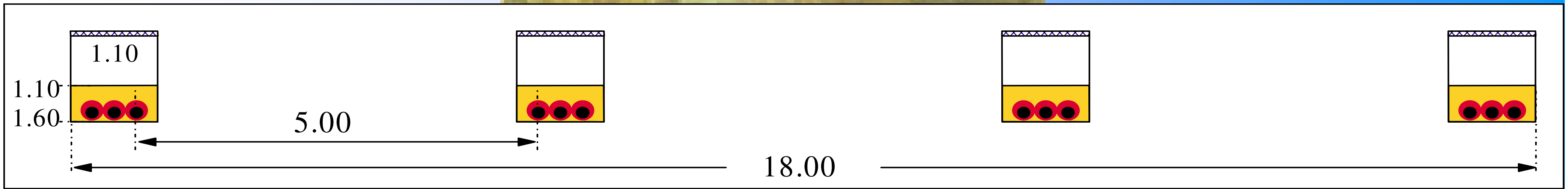
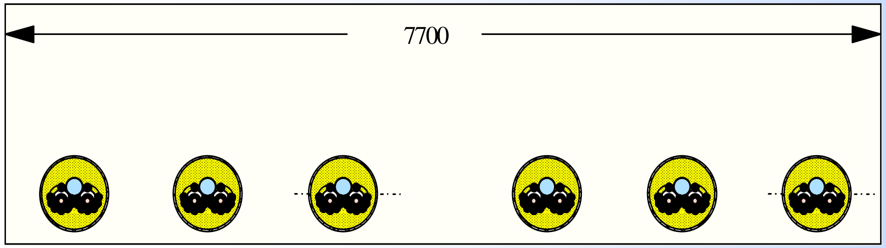
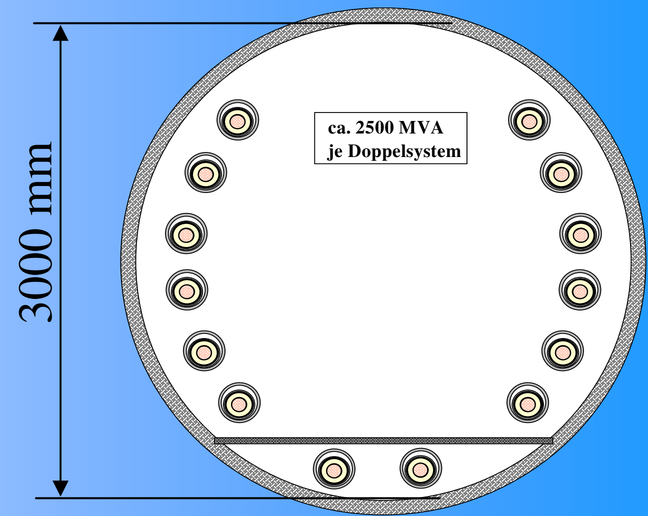
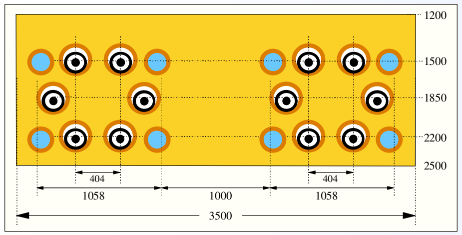
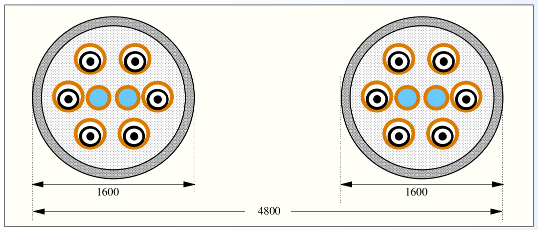



1.10
1.10
1.60
5.00
18.00


7700


3000 mm
ca. 2500 MVA
je Doppelsystem


1200
1500
1850
2200
2500
404
404
1058
1000
1058
3500


1600
1600
4800

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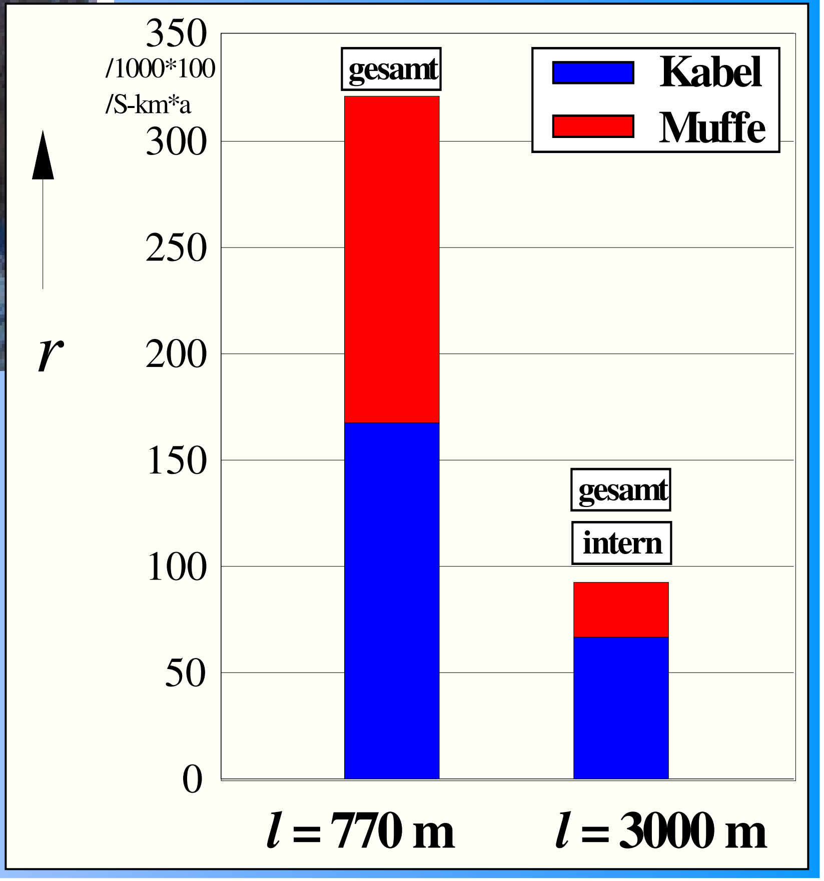
Power-Tube in an Infrastructure Conduit

delivery lengths up to 3 km…

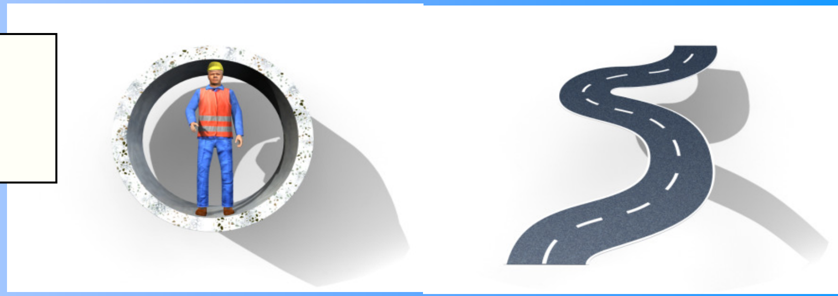


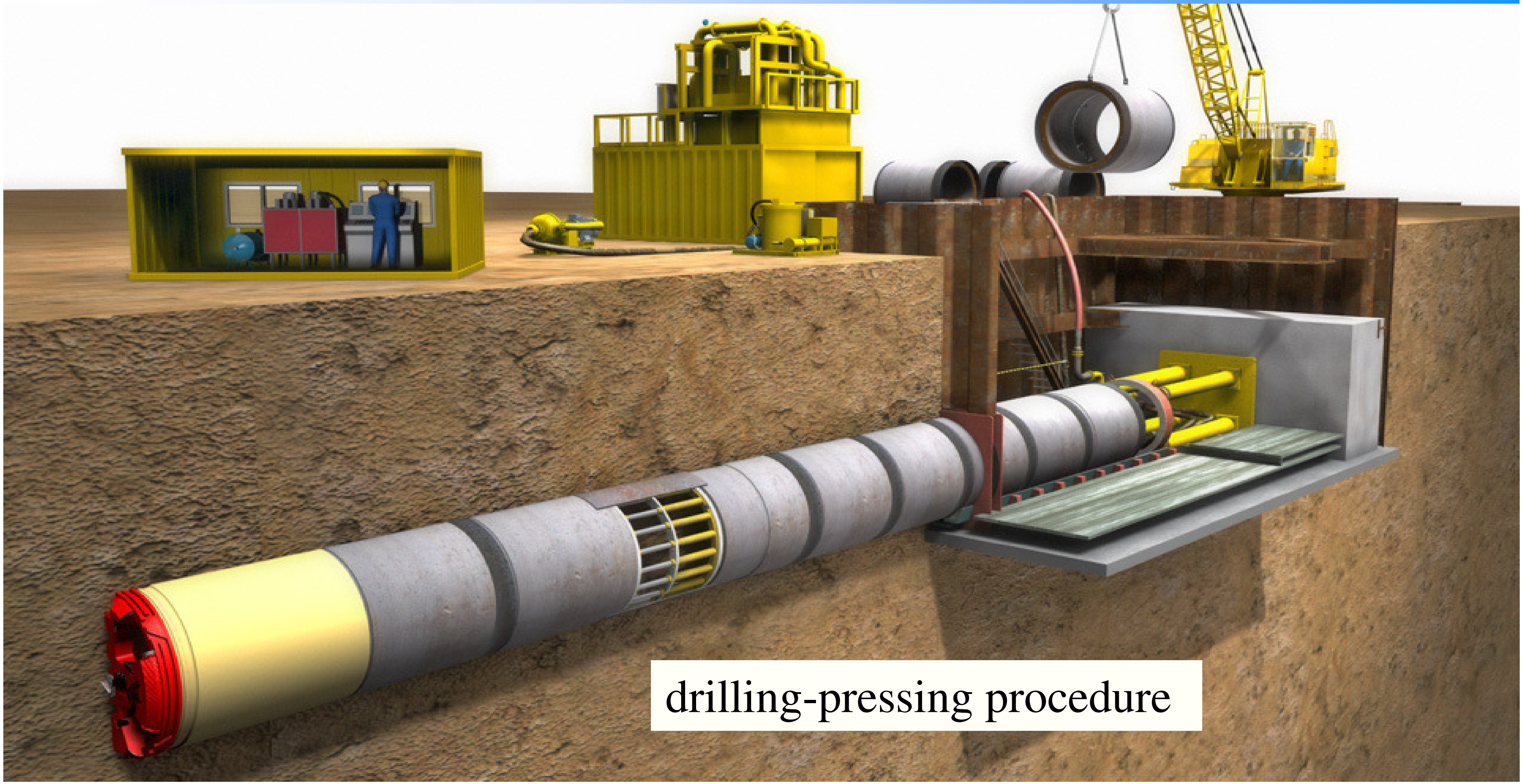
PowerTubes

Quelle: Stein&Partner

cables without additional trench need

PowerTubes





drilling-pressing procedure

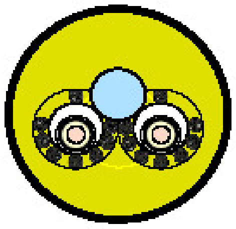
PowerTubes :

walk-in passage
by half-open
drilling-pressing procedure

costs: 50…70 %

up to 120 m/day

Advantages of PowerTube-Systems



Quellen: Uni Duisburg, nkt-cables, Prof. Stein&Partner, Dupré-Bau

- trenchless laying possible
- mechanically protected; thermally advantageous
- minimal invironmental impacts (thermal; electromagnetic)
- heat recovery, cooling and pre-cooling possible
- small trenches; in case: no additional trench
- tunnel advantages usable; tunnel problems mitigated
- decoupling of cable cores; minimal reactances
- no Cross-Bonding; minimal longitudinal voltages
- with switchable spare cores: maximal availablility

costs???

similar as with open trench arrangements:

investment cost-factor: 4…10 (**in all: 1,5…3,0**)

full cost factor: 2…5 (**in all: 1,1…2,0**)

but:

further aspects (business- and political-economical, social, energy political…etc.) relativize these additional costs !!

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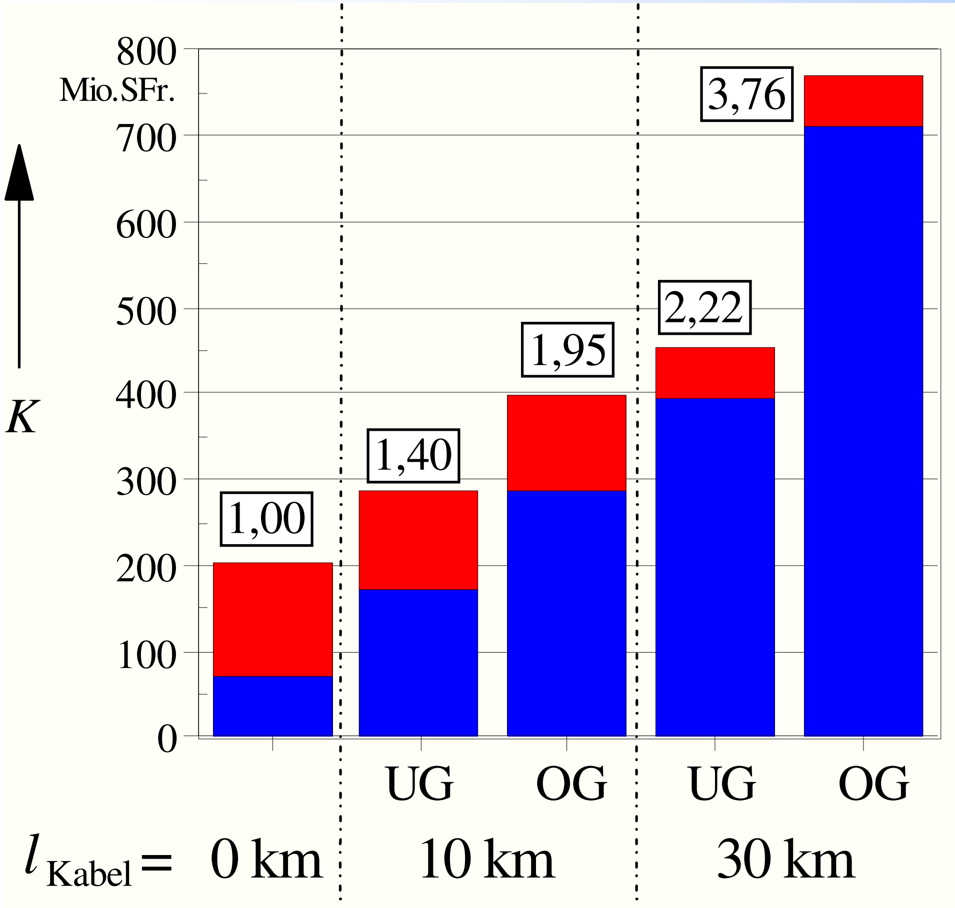
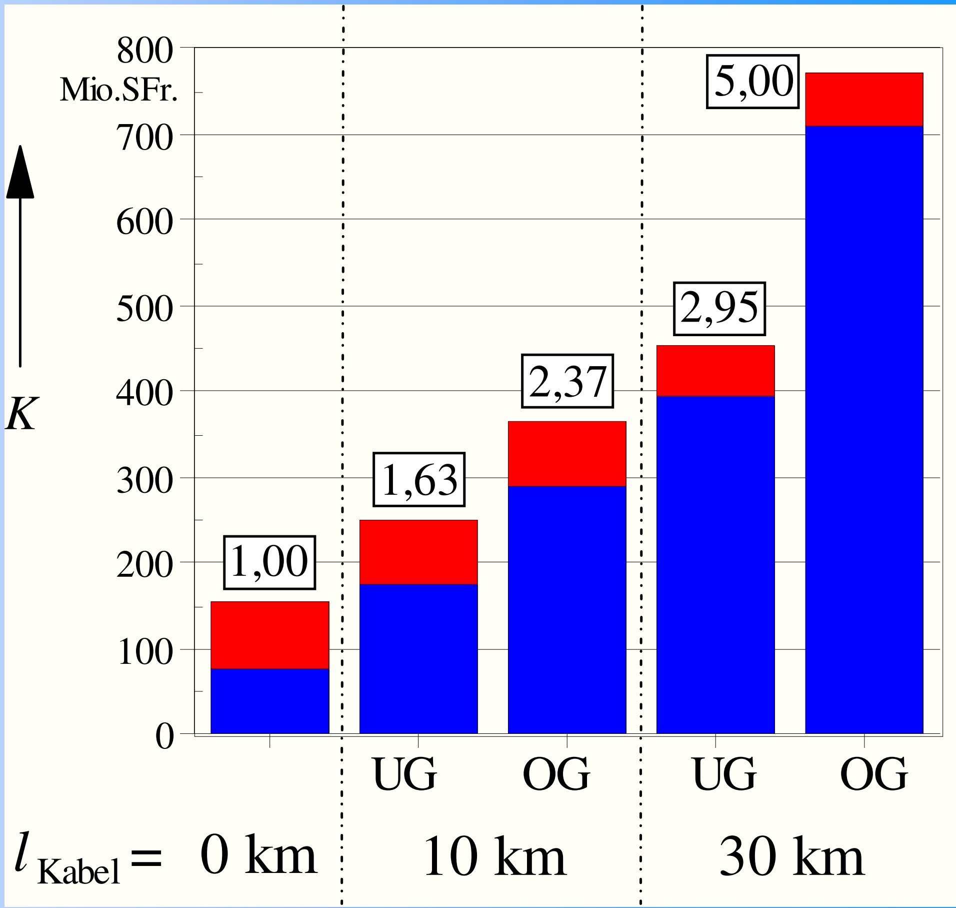
Chamoson-Chippis / Wallis



3er-Bündel 3x490; 0,100 SFr/kWh



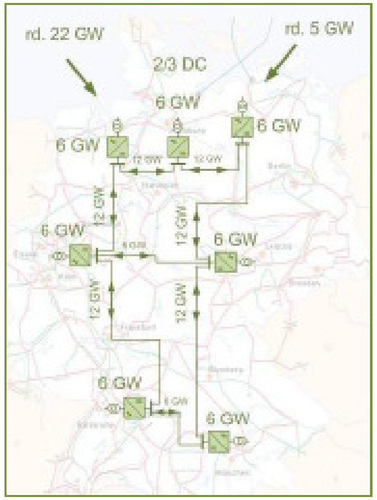
4er-Bündel 4x650; 0,100 SFr/kWh

Zusammenfassung & Ausblick

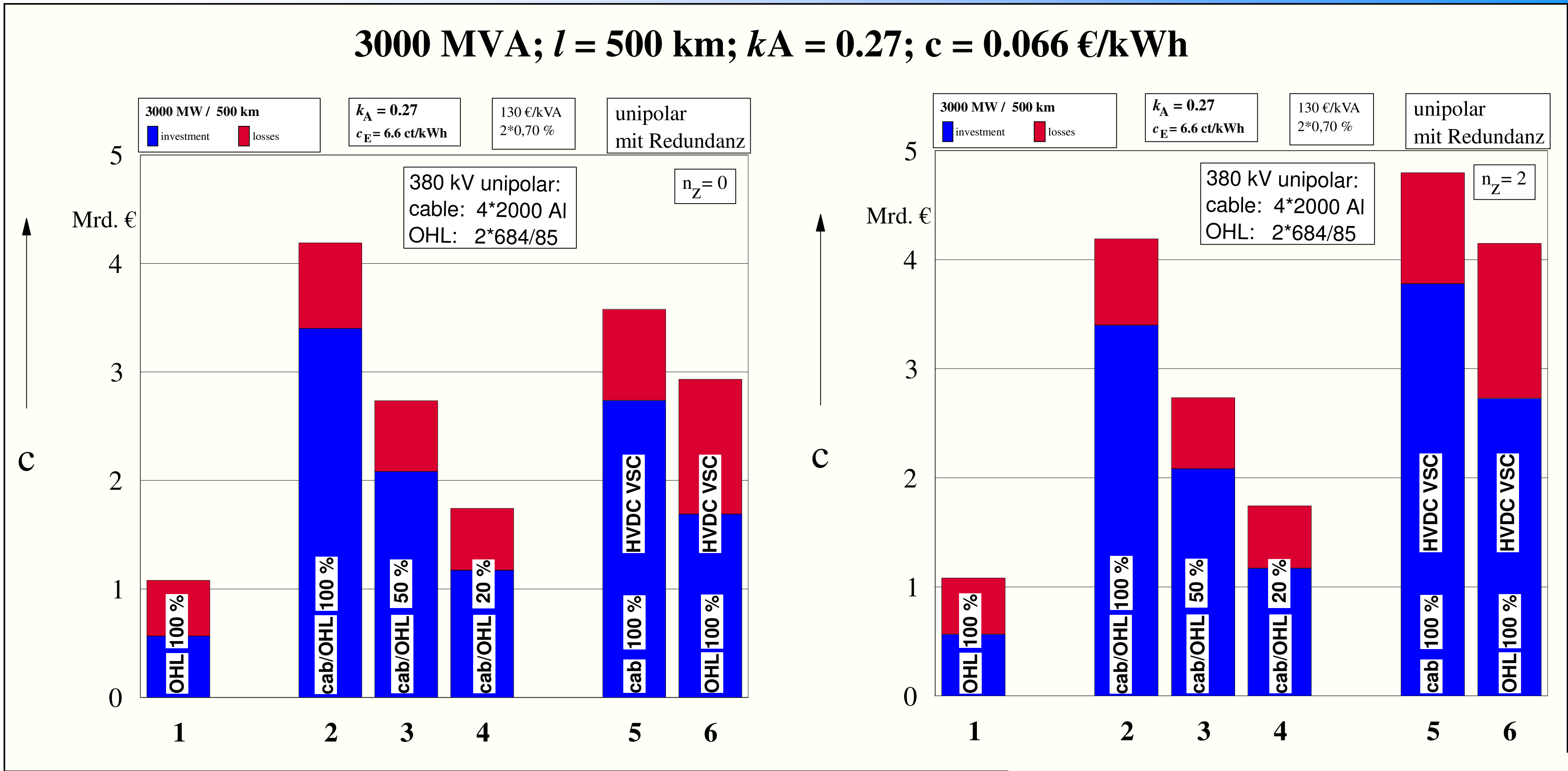
Problems with HVDC:

- high losses
- high costs
- low redundancy
- no grid potential (no circuit breakers)

- Wesentliche Komponenten für vermaschtes Overlaynetz noch nicht verfügbar
- Weiterentwicklung HGÜ-Technologie erforderlich
- Maximale Leistung HGÜ-Technologie limitiert durch Nennspannungen Kabel
- Technologievariante „Freileitung" steht zur Verfügung
- Neue Verlegetechnologien für Kabel erforderlich !!
- „Overlay-Undergrounding"-Bestrebungen generieren immensen Kabelbedarf auch bei Verfügbarkeit höherer Nennspannungen



but: PowerTubes Technologies can be applied for HVDC cables, too!

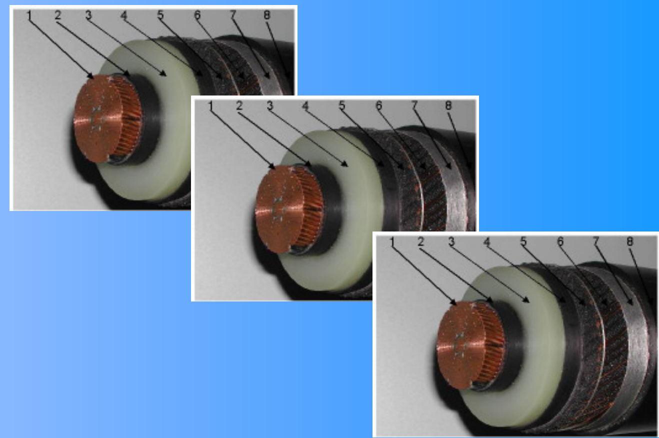


comparison of costs:
380 kV and HVDC 300 kV

SRU-study: partly cabled overlay-grid

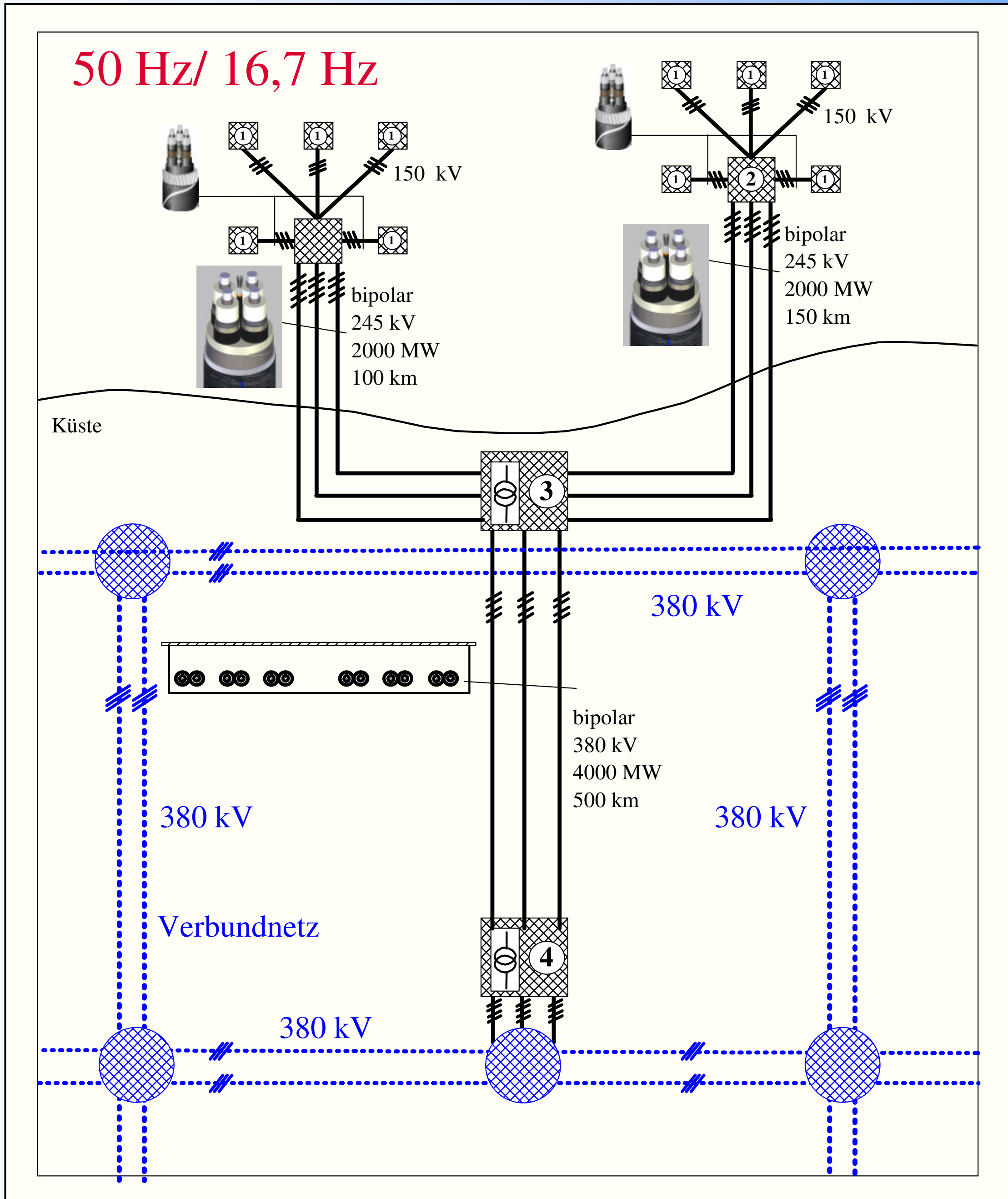
so:

or so:



this is The End !

Thank You for Your Kind Attention !

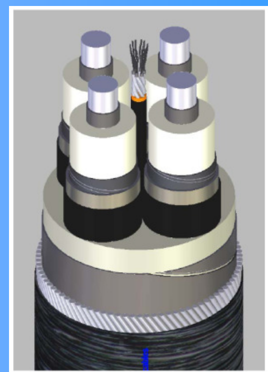


Overlay-Netz

16,7 Hz ?

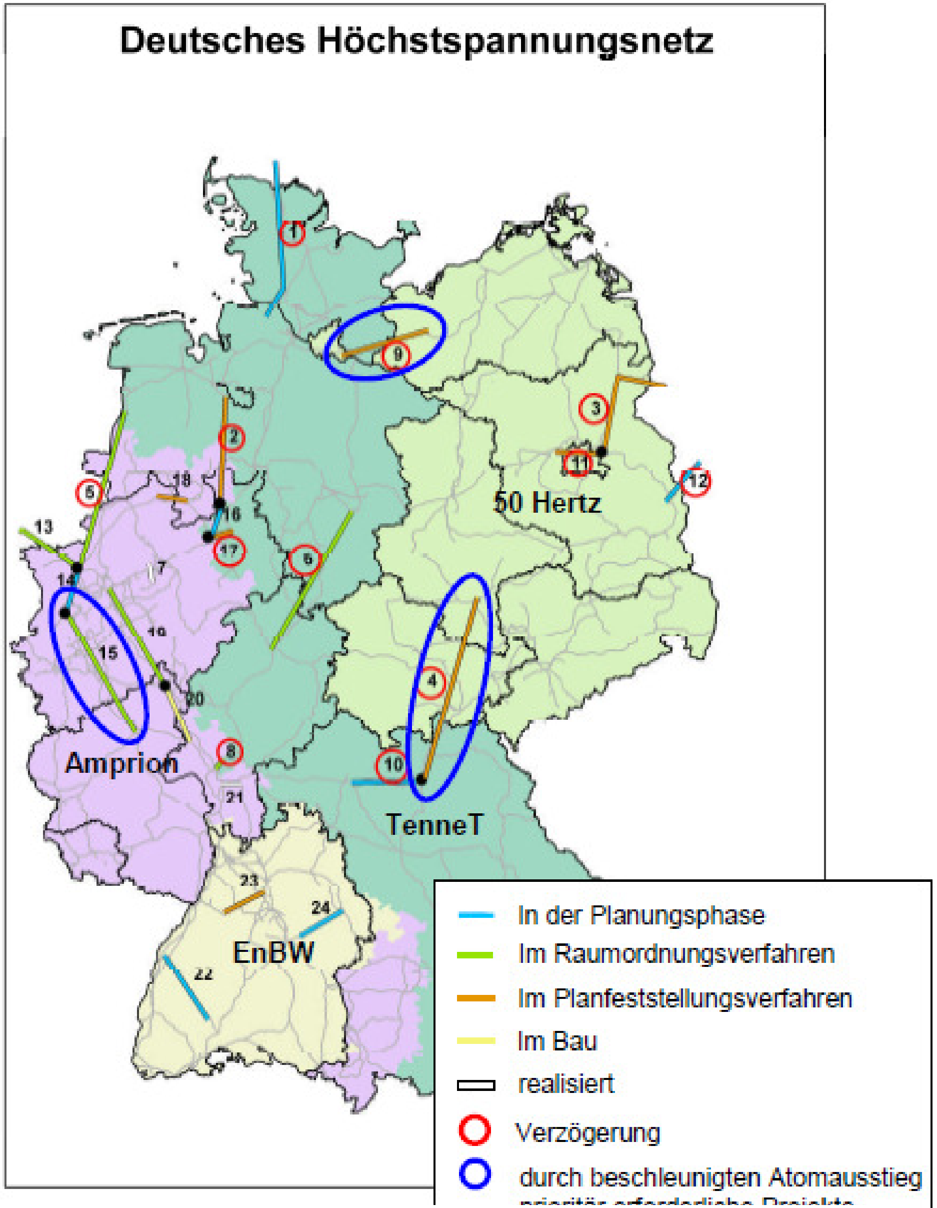
HVAC $\geq$ 500 kV ?

bipolar ?



Vorteile eines **16,7 Hz -Overlay-Netzes**:

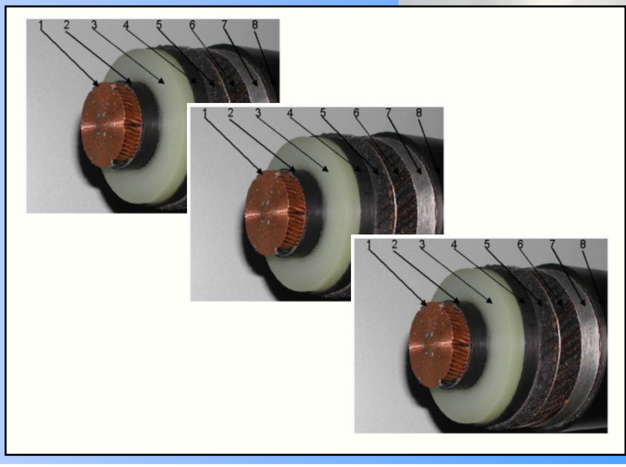
- Drehstromtechnik weitgehend verfügbar
- 500 kV-Kabel verfügbar; 750 kV-Kabel machbar
- uneingeschränkte Vernetzbarkeit
- extreme Übertragungslängen möglich
- Kabelverluste ähnlich wie HVDC-Kabel
- Regeleigenschaften wie bei HVDC
- keine zentralen offshore-Umrichteranlagen (Verluste entfallen)
- verlustarme Windpark-Verkabelung
- Einspeisung ins DB-Netz möglich

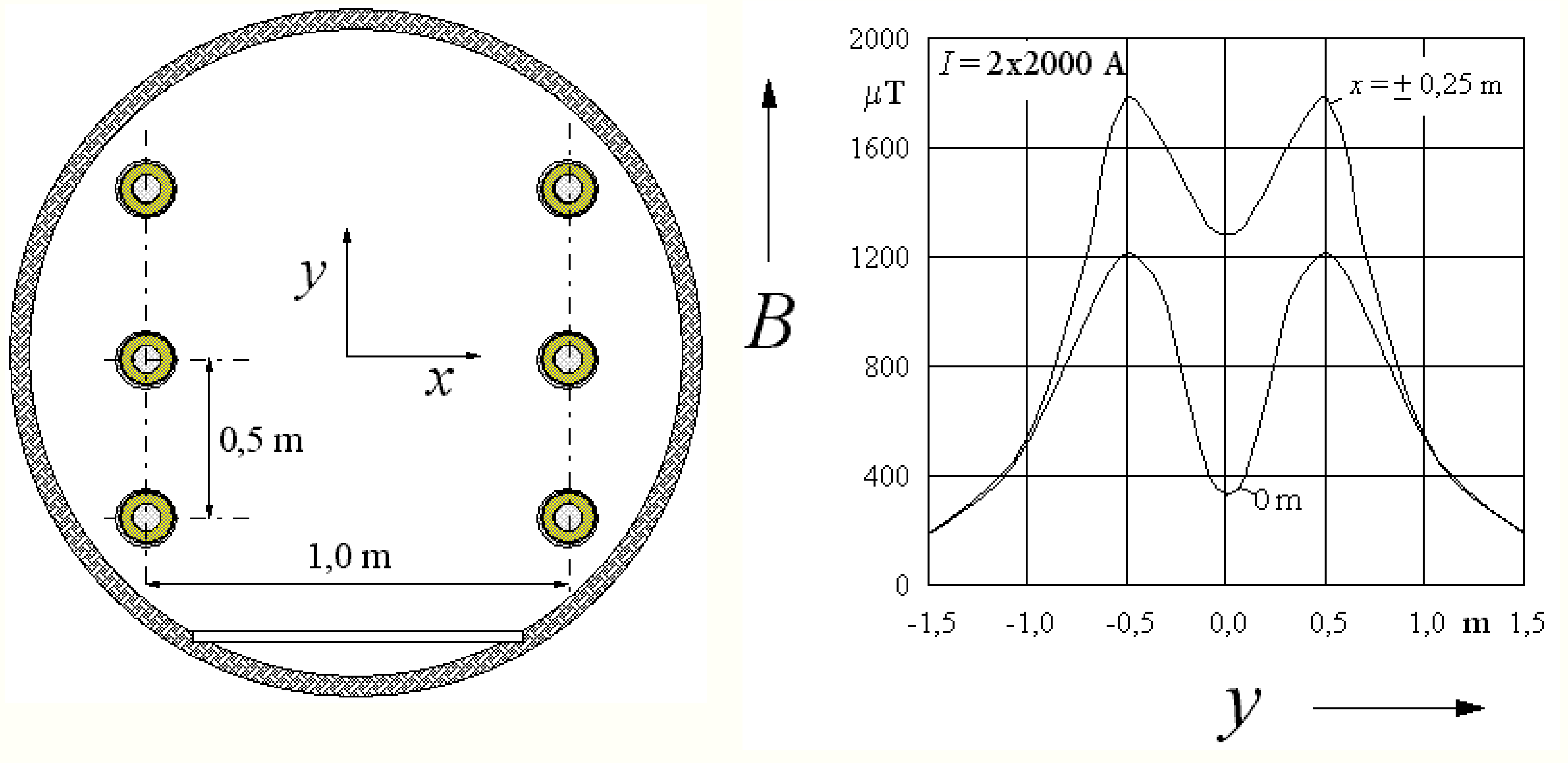


source: BNA september 2011

DENA I
(February 2005):

850 km new
380-kV-lines
up to 2015





Magnetfeld im Tunnel

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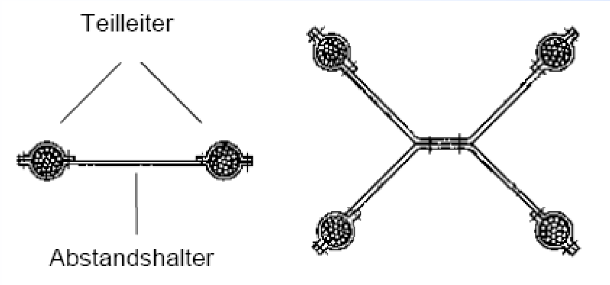
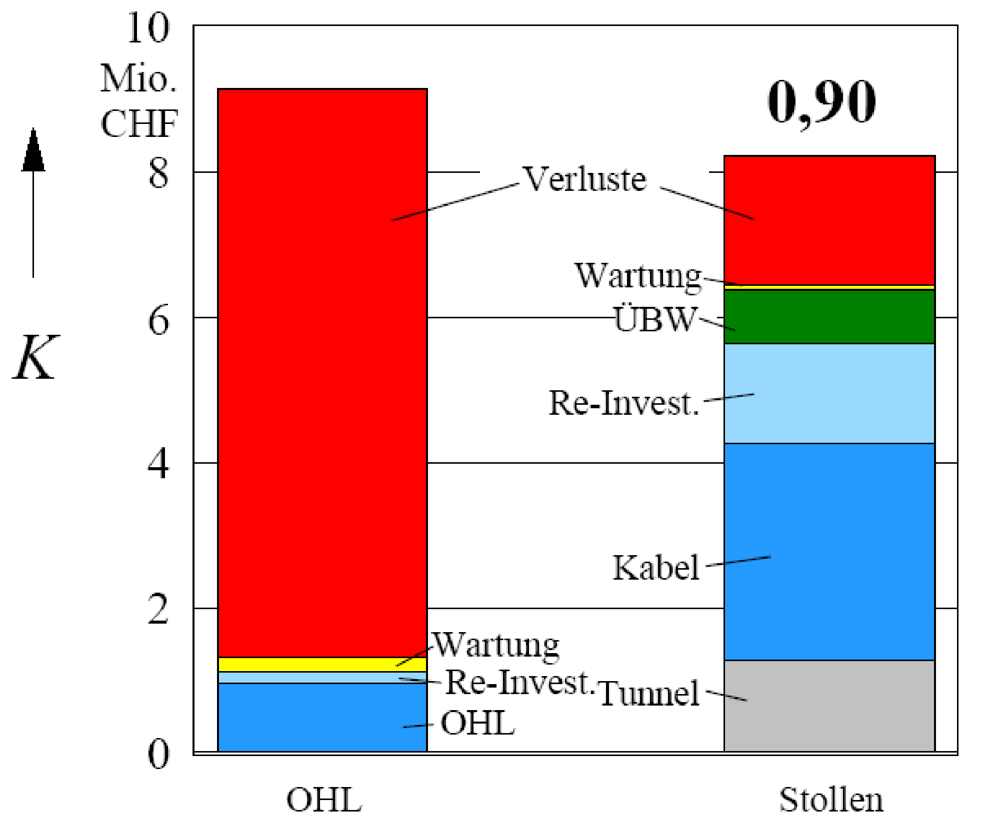
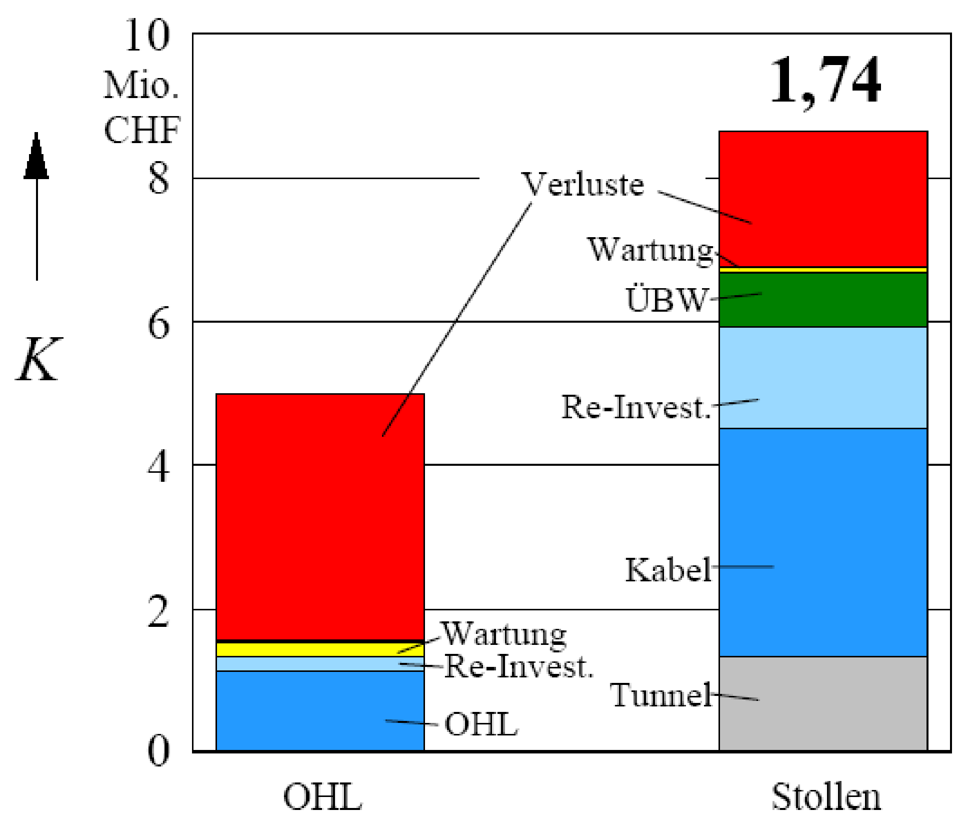


Riniken/Schweiz





2er-Bündel 2x635 Al; Umwegfaktor 1,37

3er-Bündel 3x635 Al; Umwegfaktor 1,0