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EPR | ELECTRIC POWER
RESEARCH INSTITUTE

Thursday, September 13, 2007
Friday, September 14, 2007

EPRI HVDC Conference

HVDC Solutions for System Interconnection and Advanced Grid Access

Joerg Dorn Dietmar Retzmann Cristen Schimpf Dag Soerangr

Global Trends

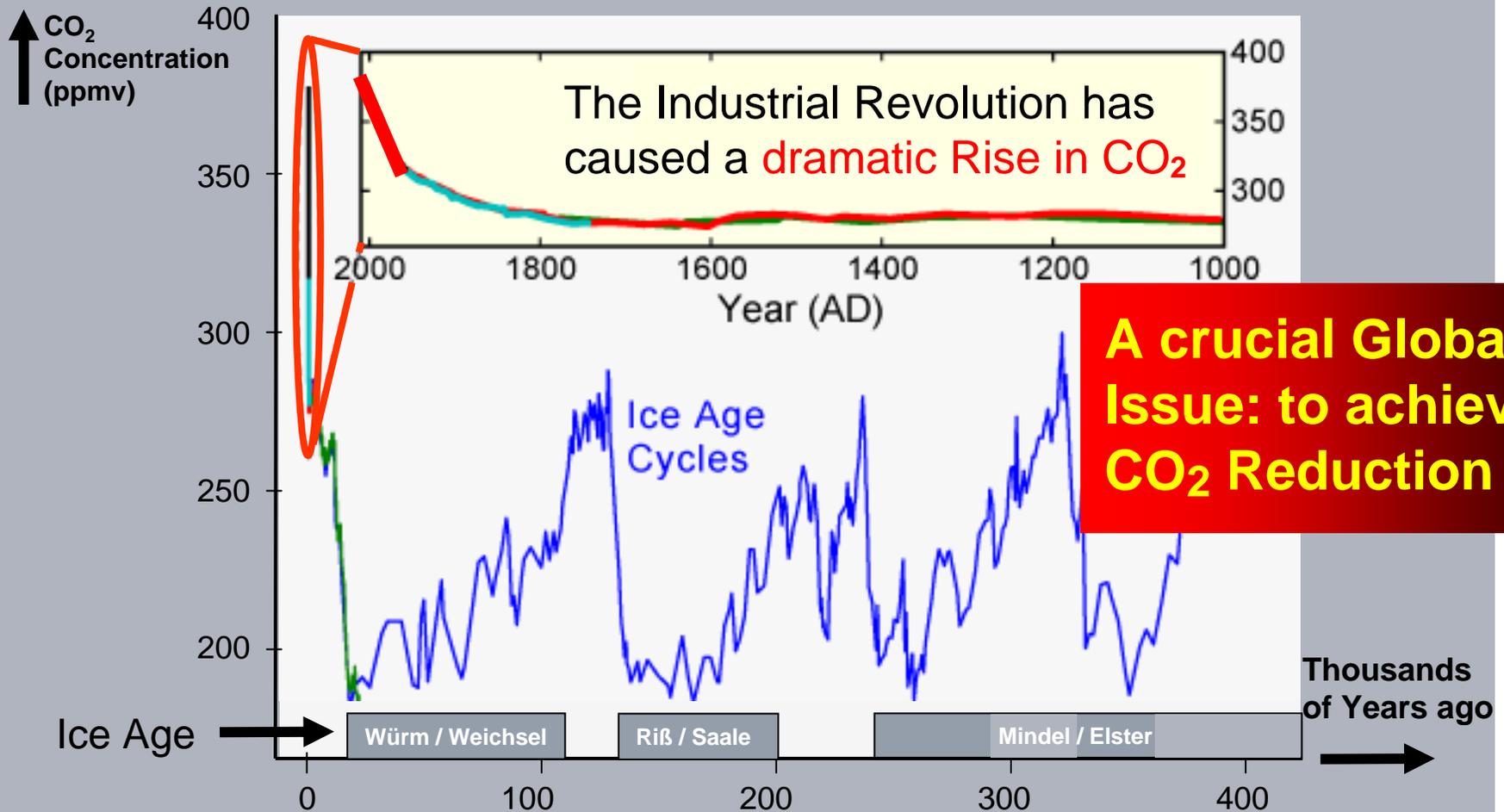
on Power Markets

CO₂ Reduction – Green Energy

Megacities – Security of Supply

Conclusions of IPCC: **CO₂ Increase** due to **human Influence** is much higher than natural Fluctuation

Carbon Dioxide Variations in the Air



Sources: Siemens PTD TI, Wikipedia, 2006

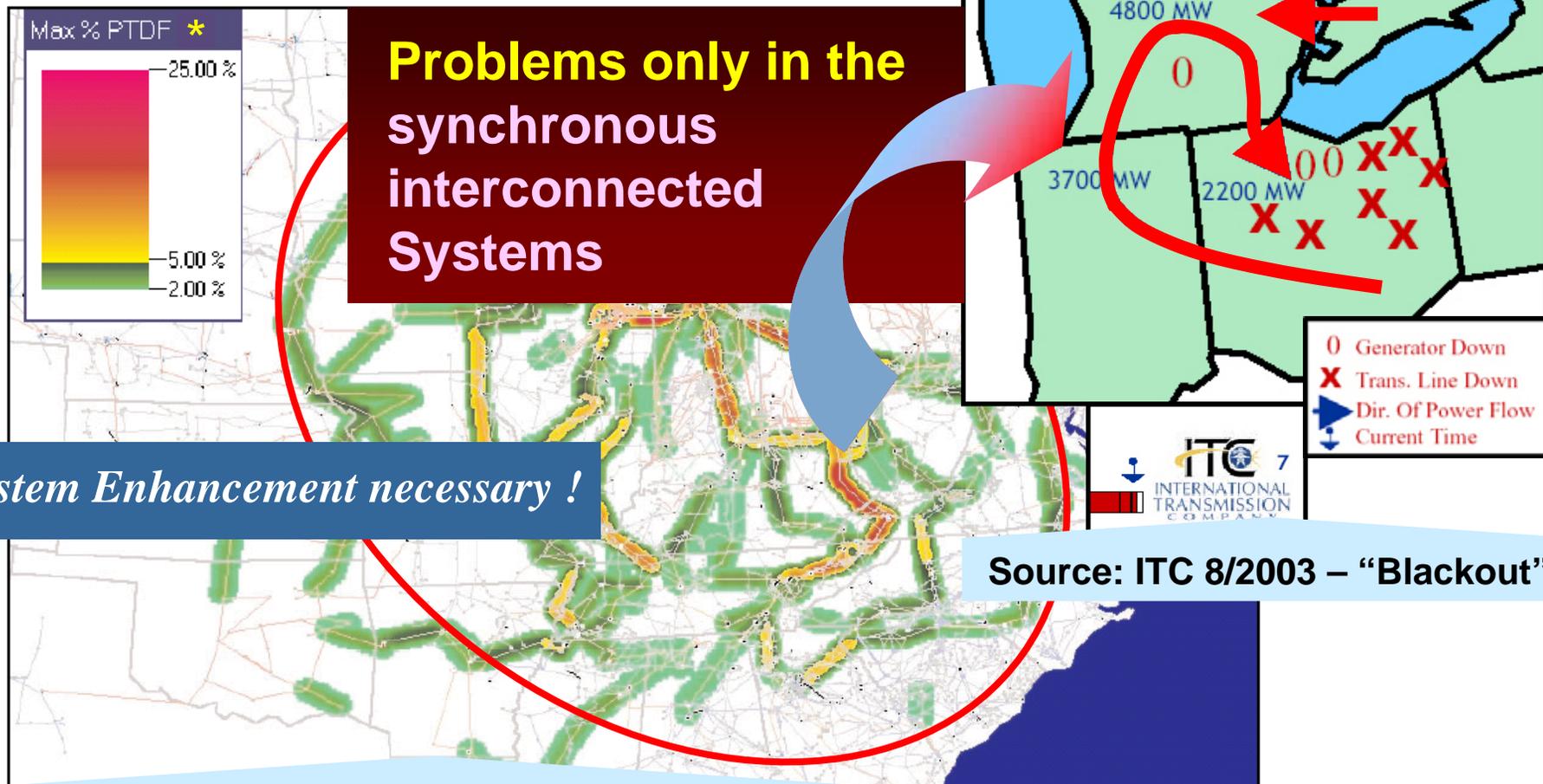


Task 1
Security

of Power Supply

If Power Flow exceeds the Design Criteria: **Blackout** **SIEMENS**

Figure 3: Loop Flow of Power Transfer from Wisconsin to TVA



System Enhancement necessary !

Source: National Transmission Grid Study; U.S. DOE 5/2002 – “Preview”

The US Blackout 2003: Congestion, Overloads and Loop Flows

* **PTDF** = Power Transfer Distribution Factor



Task **2**
Sustainability
of **Power Supply**



Extensions of Interconnected Systems



Increased Power Exchange among the Interconnected Systems



Transmission of large Power Blocks over long Distances (Hydro, Wind * and Solar Energy)

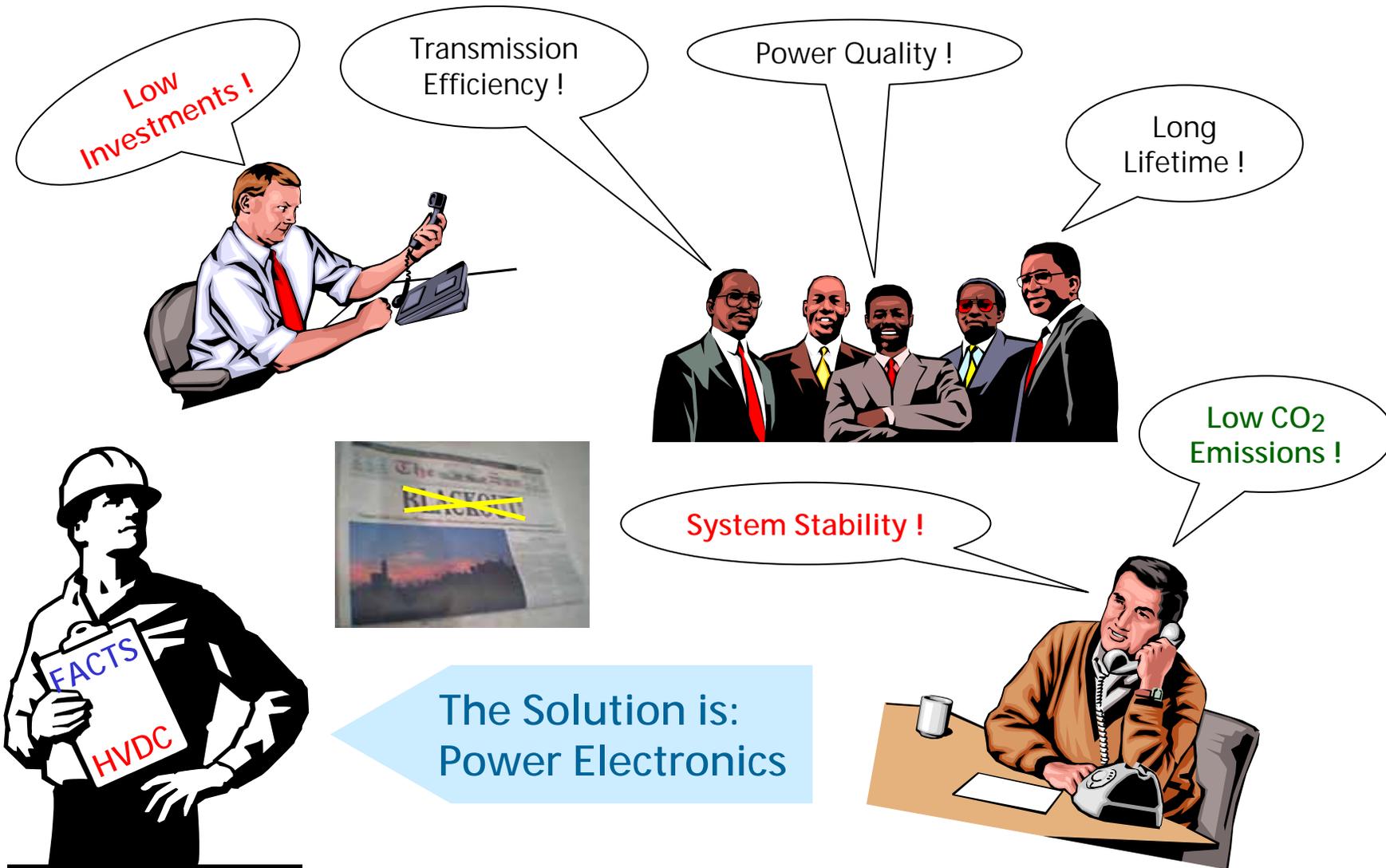


Renewable Energy Resources at favorable Locations *

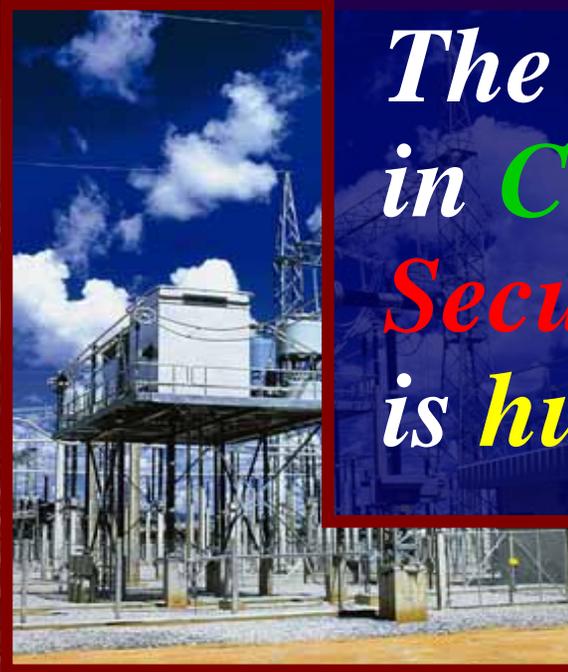
*** A big Issue for the Grid Developments – in all Countries**

Today's Challenges for a Solution Provider

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*The Global Potential
in **CO₂ Reduction** and
Security Enhancement
is huge*



Use of **Advanced Solutions**
for **Power Transmission**



HVDC

High Power DC

Transmission

Systems

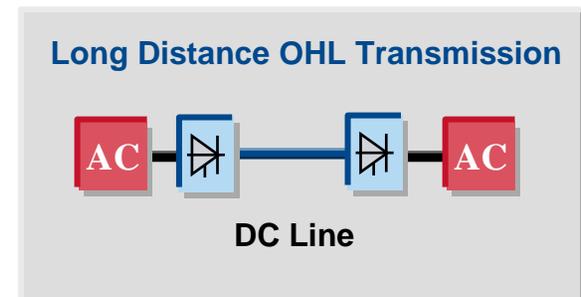
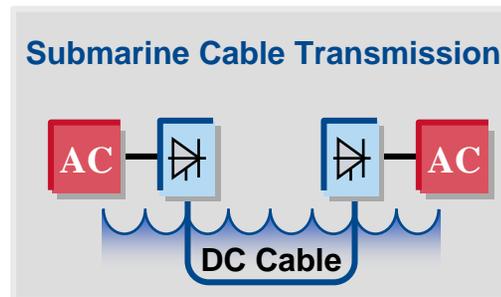
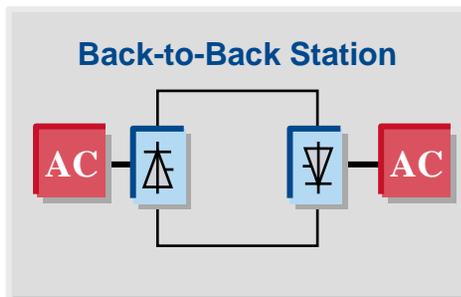
HVDC - High Voltage DC Transmission: It makes P flow

- HVDC “Classic” with LT Thyristors* (Line-commutated Converter)
- HVDC “Bulk” with 800 kV – for 5,000 MW to > 7,000 MW
- HVDC PLUS (Voltage-Sourced Converter – VSC)
- HVDC can be combined with FACTS
- V-Control included

800 kV for minimal Line Transmission Losses

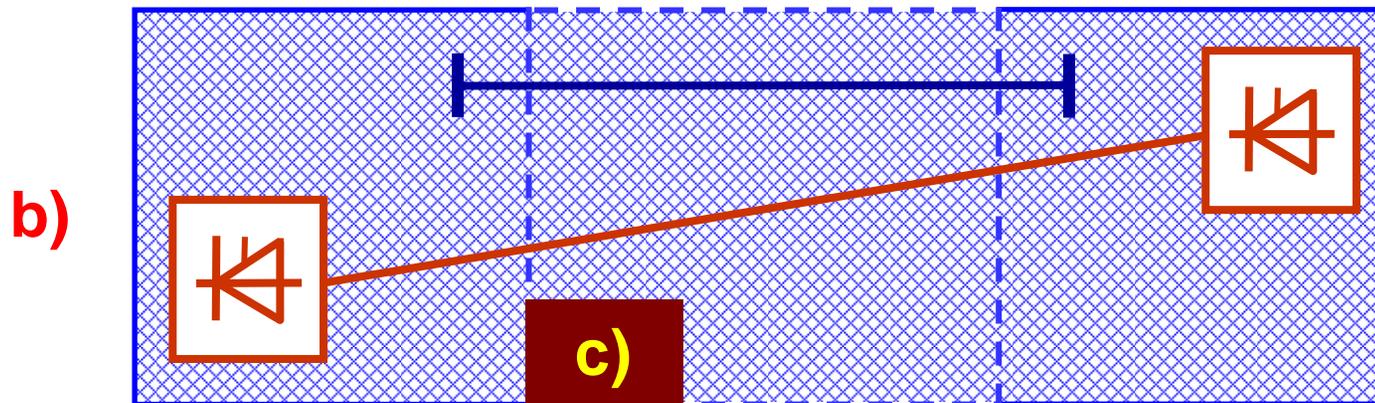
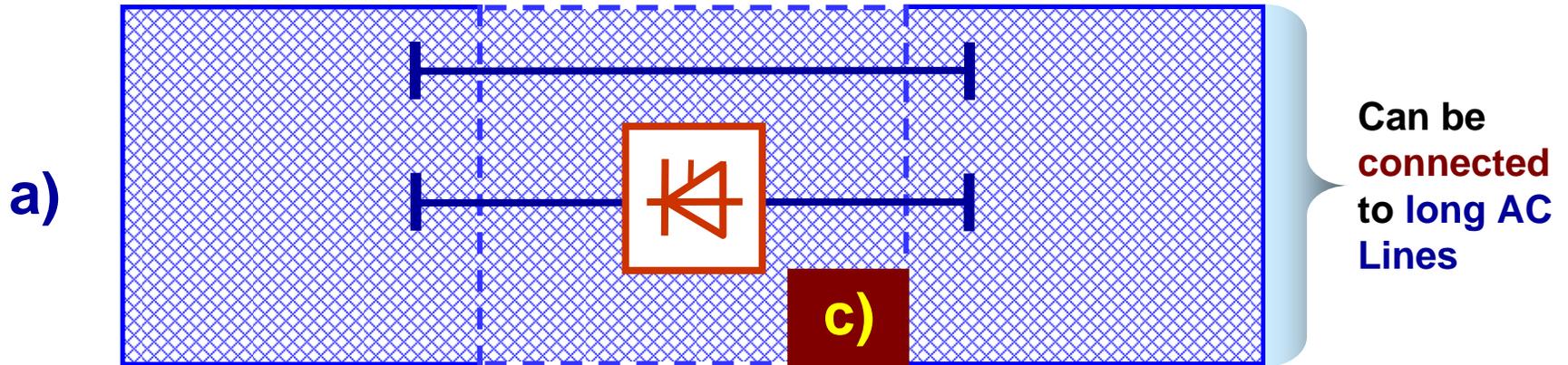
HVDC-LDT - Long Distance Transmission

B2B - The Short Link



* LTT = Light-Triggered Thyristor with integrated Break-over Protection

Options of HVDC Interconnections



a) **Back-to-Back Solution**

b) **HVDC Long Distance Transmission**

c) **Integration** of HVDC into the AC System

Basslink HVDC: remote Infeed of

Green Energy

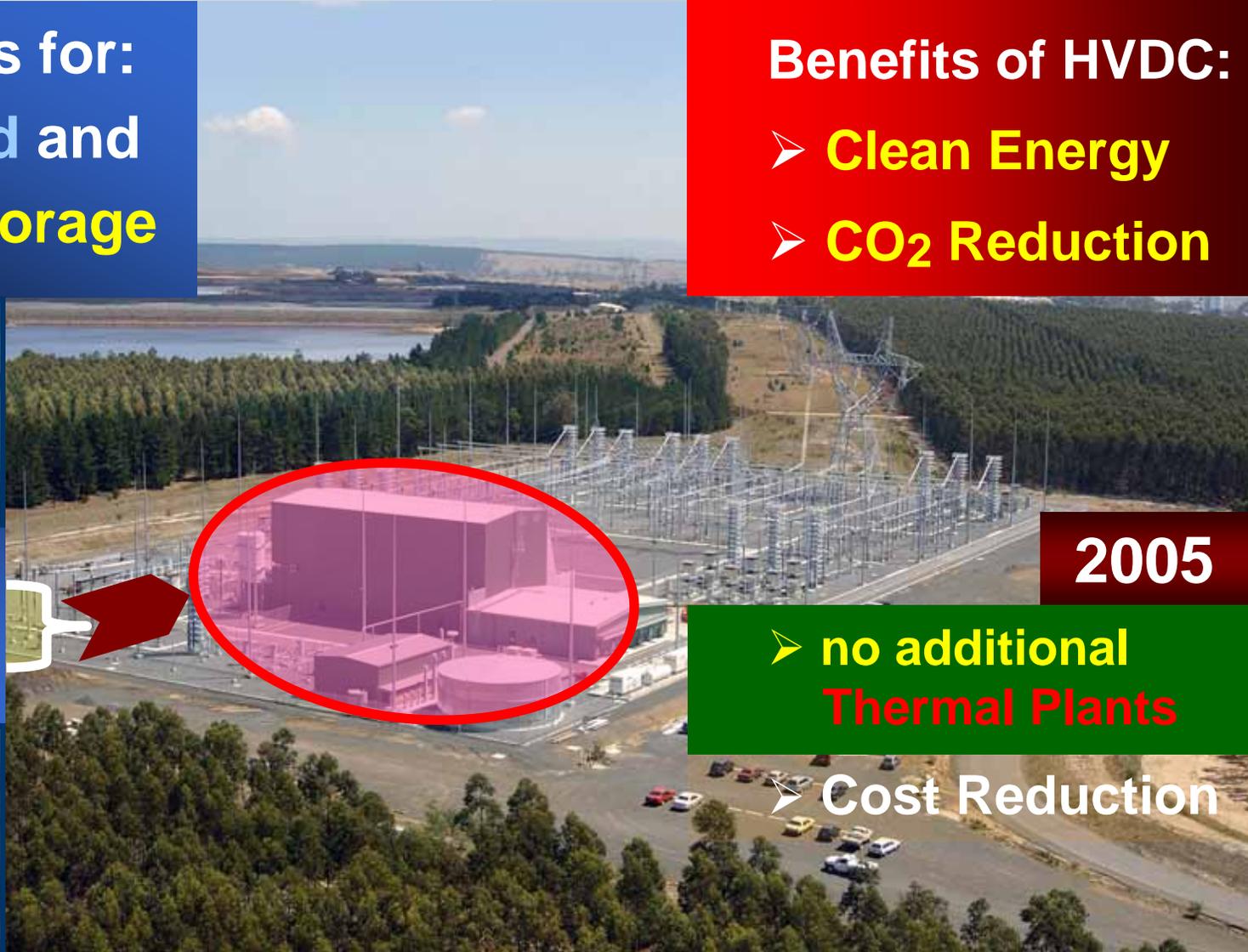
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Hydro Plants for:

- Base Load and
- Energy Storage



Plus Wind Power



Benefits of HVDC:

- Clean Energy
- CO₂ Reduction

- no additional Thermal Plants

- Cost Reduction

Covering Base and Peak-Load Demands

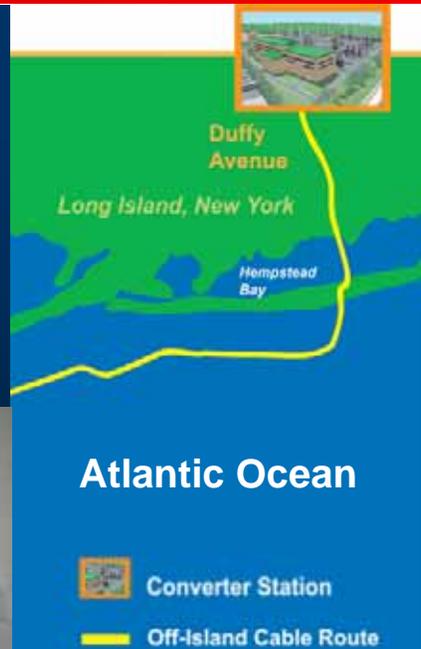
Transmission and Distribution

New DC Cable Link Neptune RTS, USA



Ed Stern, President of Neptune RTS: "High Voltage Direct Current Transmission will play an increasingly important Role, especially as it becomes necessary to tap Energy Reserves whose Sources are far away from the Point of Consumption"

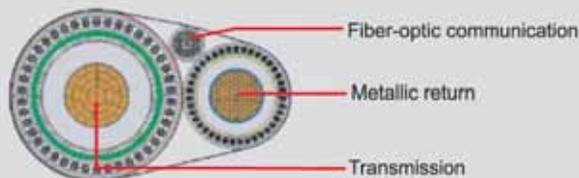
Safe and reliable Power Supply for the Megacities – "Blackout Prevention"



Customer:	Neptune RTS	
End User:	Long Island Power Authority (LIPA)	
Location:	New Jersey: Sayreville Long Island: Duffy Avenue	
Project Development:	NTP-Date:	07/2005
	PAC:	07/2007
Supplier:	Consortium Siemens / Prysmian	
Transmission:	Sea Cable – 500 kV	
Power Rating:	600/660 MW monopolar	
Transmission Dist.:	82 km DC Sea Cable 23 km Land Cable	

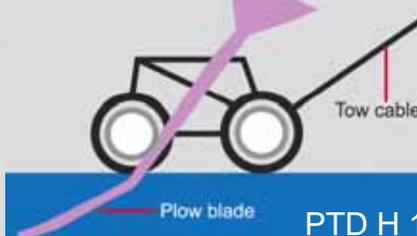


Pirelli power cable cross-section



15 09-2007

Hydroplow



PTD H 1 MT/Re

Power Transmission and Distribution

Neptune HVDC: 660 MW Full Power Delivery **SIEMENS**

in Trial Operation – 2 Weeks ahead of Schedule

Blackout in **New York City** – June 27, 2007



385,000 People without Electricity in Manhattan and Bronx: Subway broke down, Traffic Lights out of Operation – up to 1 hour Power Outage



New Jersey: Sayreville

Neptune HVDC successfully supported **Long Island's Power Supply** - 700,000 Households could be saved



Long Island: Duffy Avenue

Power Transmission and Distribution

Europe – The HVDC Portfolio is growing

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Storebælt

- Customer:
Energinet.dk
- System Data:

Rating	600 MW
Voltage	400 kV DC
Thyristor	8 kV LTT
Cable Length	56 km



BritNed

- Customer:
BritNed Development Ltd.
- System Data:

Rating	1000 MW
Voltage	400 kV DC
Thyristor	8 kV LTT
Cable Length	200 km



- Energy Exchange by Sea Cable
- Sharing of Reserve Capacity
- No Increase in Short-Circuit Power

Siemens received the Order for the World's first 800 kV HVDC in China Southern Power Grid

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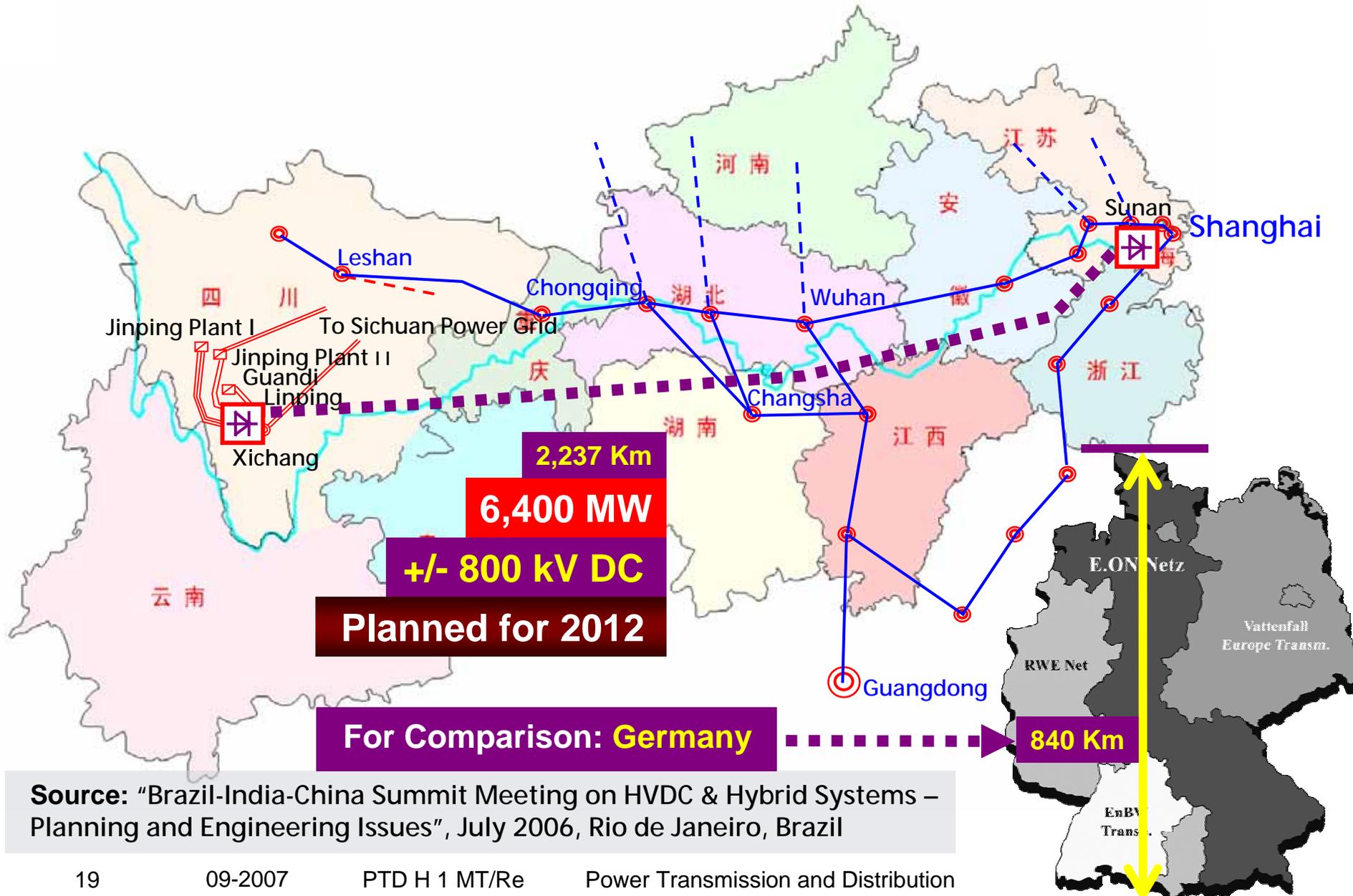
Siemens – the Leader in Bulk Power DC Transmission Technology



Reduction in CO₂ → versus local Power Supply with Energy-Mix
32.9 m tons p.a. - by using Hydro Energy and HVDC for Transmission

Jinping ± 800 kV HVDC Transmission Project

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Grid Extension in India - Hybrid AC plus DC

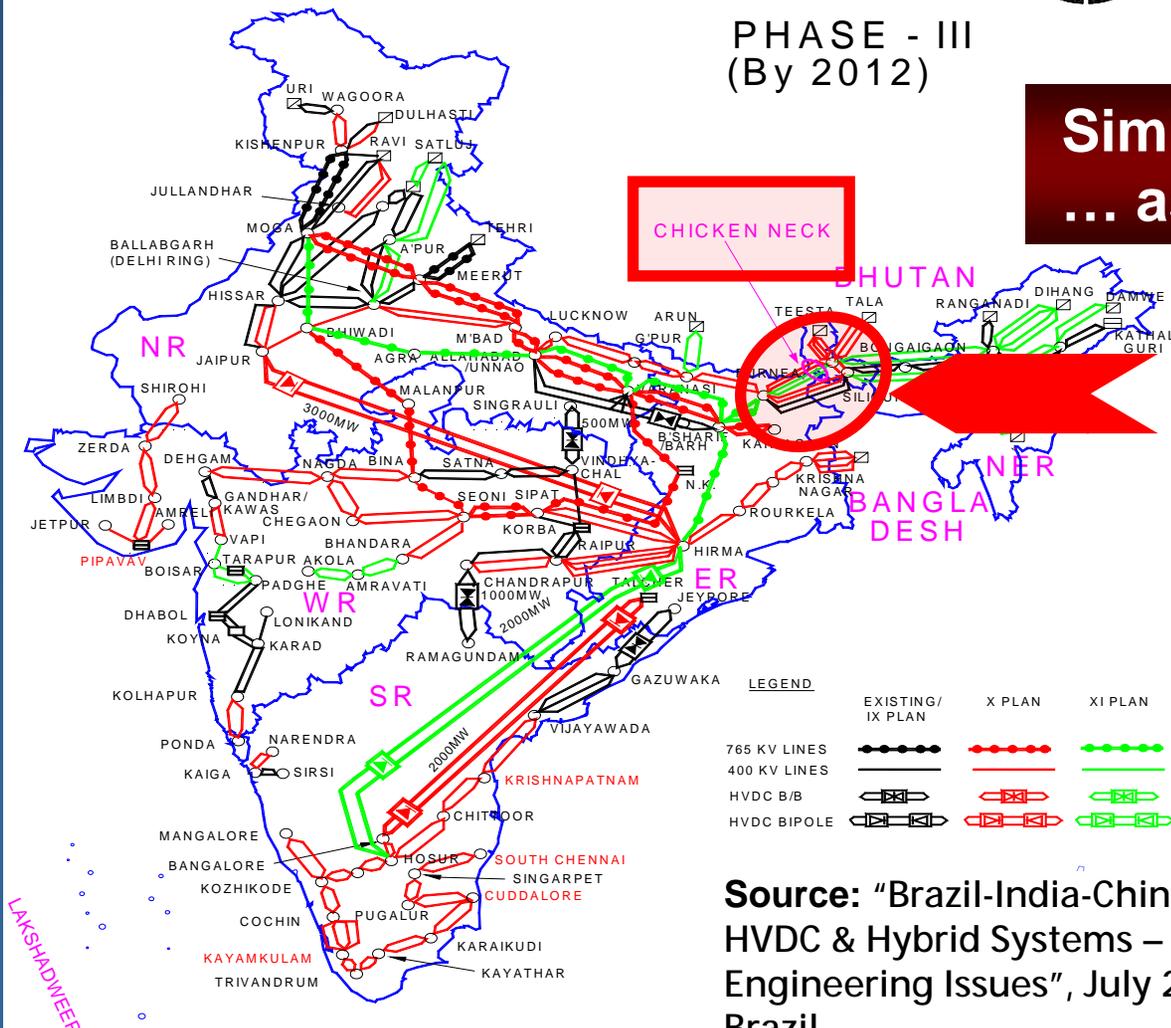
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DEVELOPMENT OF NATIONAL GRID



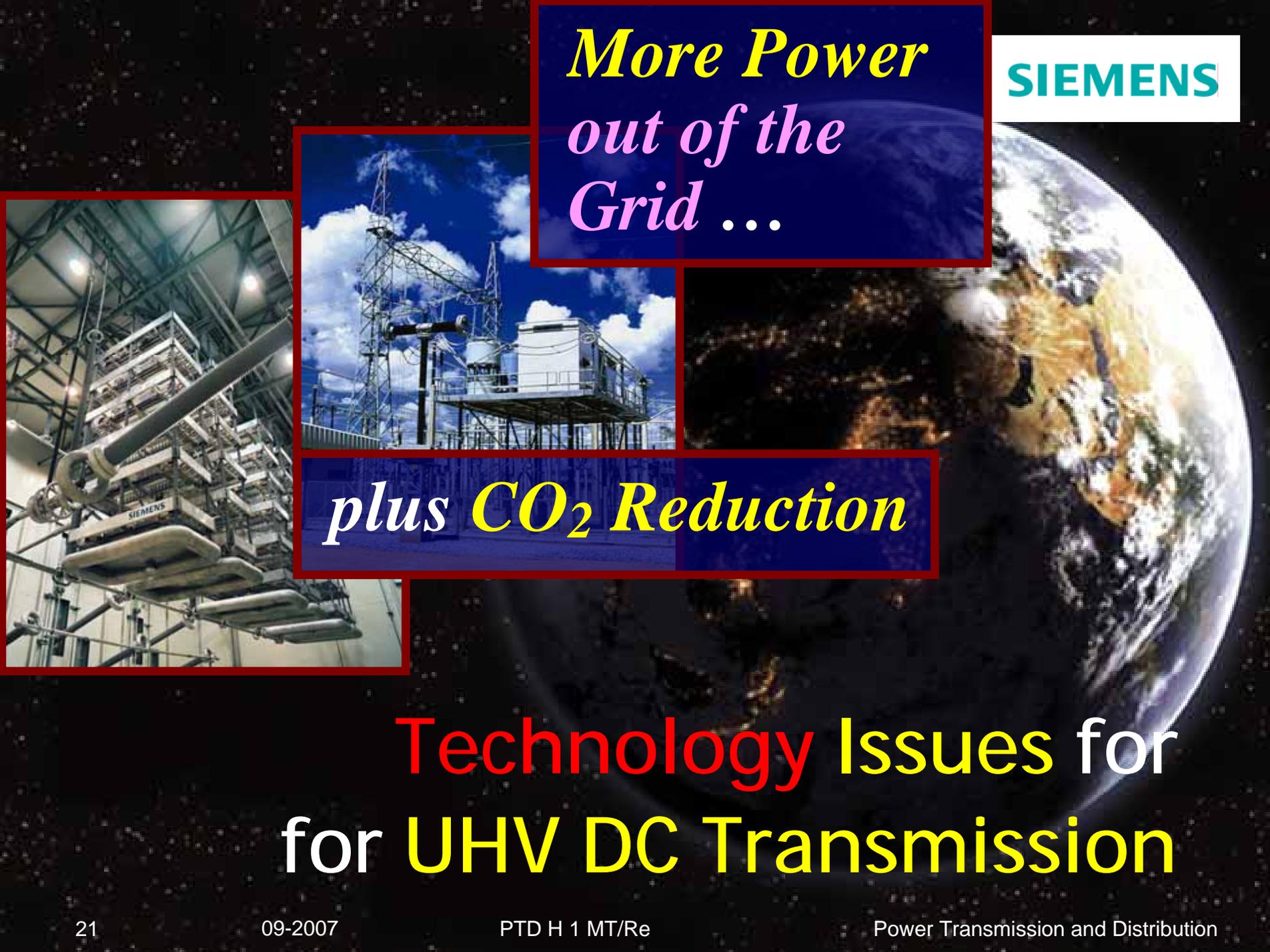
PHASE - III
(By 2012)

Similar Prospects
... as in China



Source: "Brazil-India-China Summit Meeting on HVDC & Hybrid Systems – Planning and Engineering Issues", July 2006, Rio de Janeiro, Brazil

Prospects in China and India: "Smart" and Strong Grids

The background of the slide is a high-resolution image of the Earth as seen from space, showing the curvature of the planet, clouds, and the dark void of space.

*More Power
out of the
Grid ...*

An inset image in the upper middle section shows a power substation with several tall metal towers and power lines against a blue sky with white clouds.

plus CO₂ Reduction

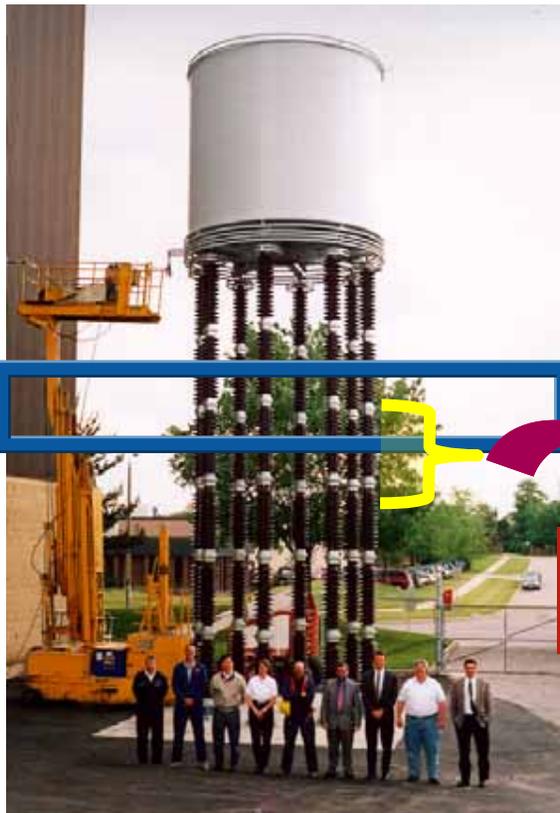
An inset image on the left side shows a large, complex industrial structure, likely a power transformer or switchgear, with various pipes, valves, and metal frameworks. The Siemens logo is visible on one of the components.

**Technology Issues for
for UHV DC Transmission**

Air-Core, Air-cooled Smoothing Reactor and Converter Transformer – The Dimensions are “huge”

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500 kV DC in the Pictures – are now being extended to **800 kV DC**



Mostly an **Issue of Mechanics** –

but **not only ...**

UHV DC Reactor – in Test Field

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800 kV DC
3,125 A
75 mH
28 tons !



UHV DC Bushing at Test Lab TU Graz – Austria

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800 kV DC Bushing in Test Field



800 kV HVDC Transformer under Construction

320 MVA Single-Phase* Transformer

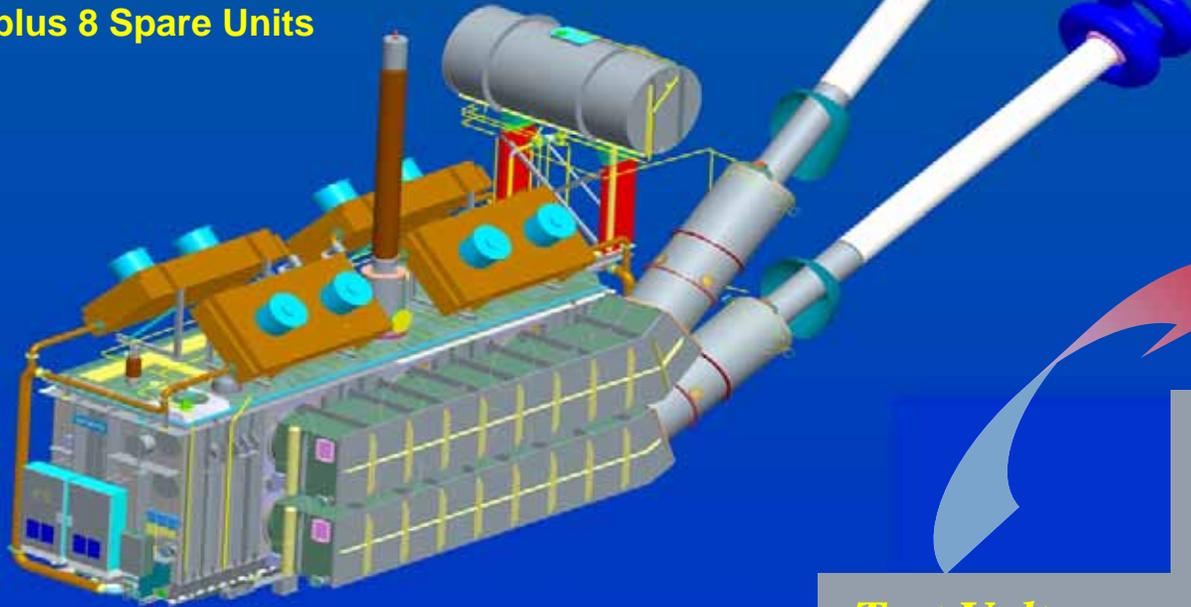
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*48** Transformers – for the Yunnan-Guangdong UHV DC Project*

Core Design: 3 Limbs & 2 Return Limbs
L x W x H: 26 x 6.4 x 15.2 m
Total Weight: 512 tons

* for Transportation Reasons

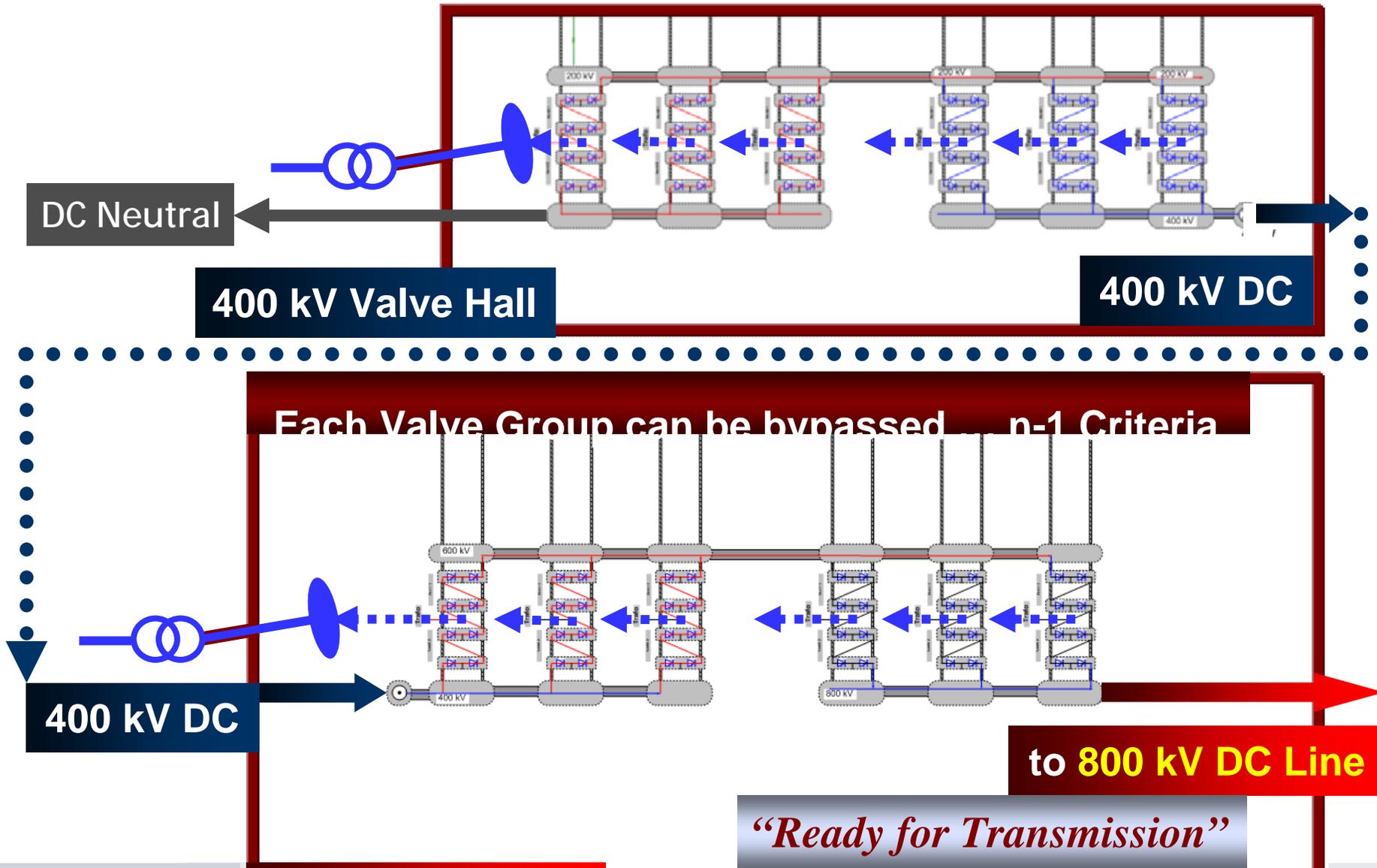
** plus 8 Spare Units



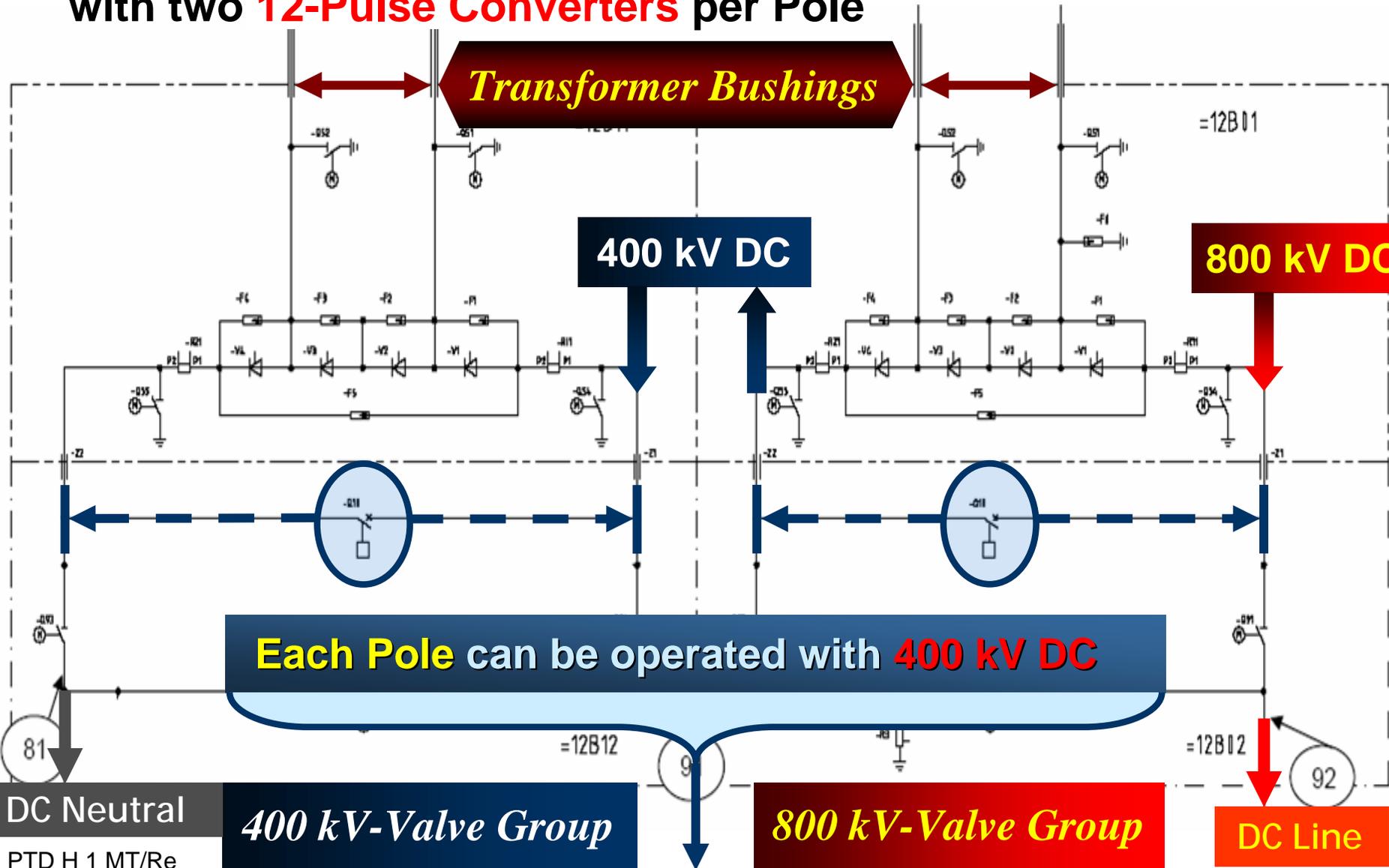
Test Voltages

AC (1 min)	1,020 kV
SI	1,790 kV
LI (FW/CW)	2,080/2,320 kV
DC (2 hrs)	1,175 kV
PR (90/90/45 min)	935 kV

Valve Hall Configuration – for UHV DC SIEMENS



N-1 Criteria: fully redundant HVDC Scheme – with two 12-Pulse Converters per Pole



DC Neutral

PTD H 1 MT/Re

“Snapshots” from DC Valve Tower Testing

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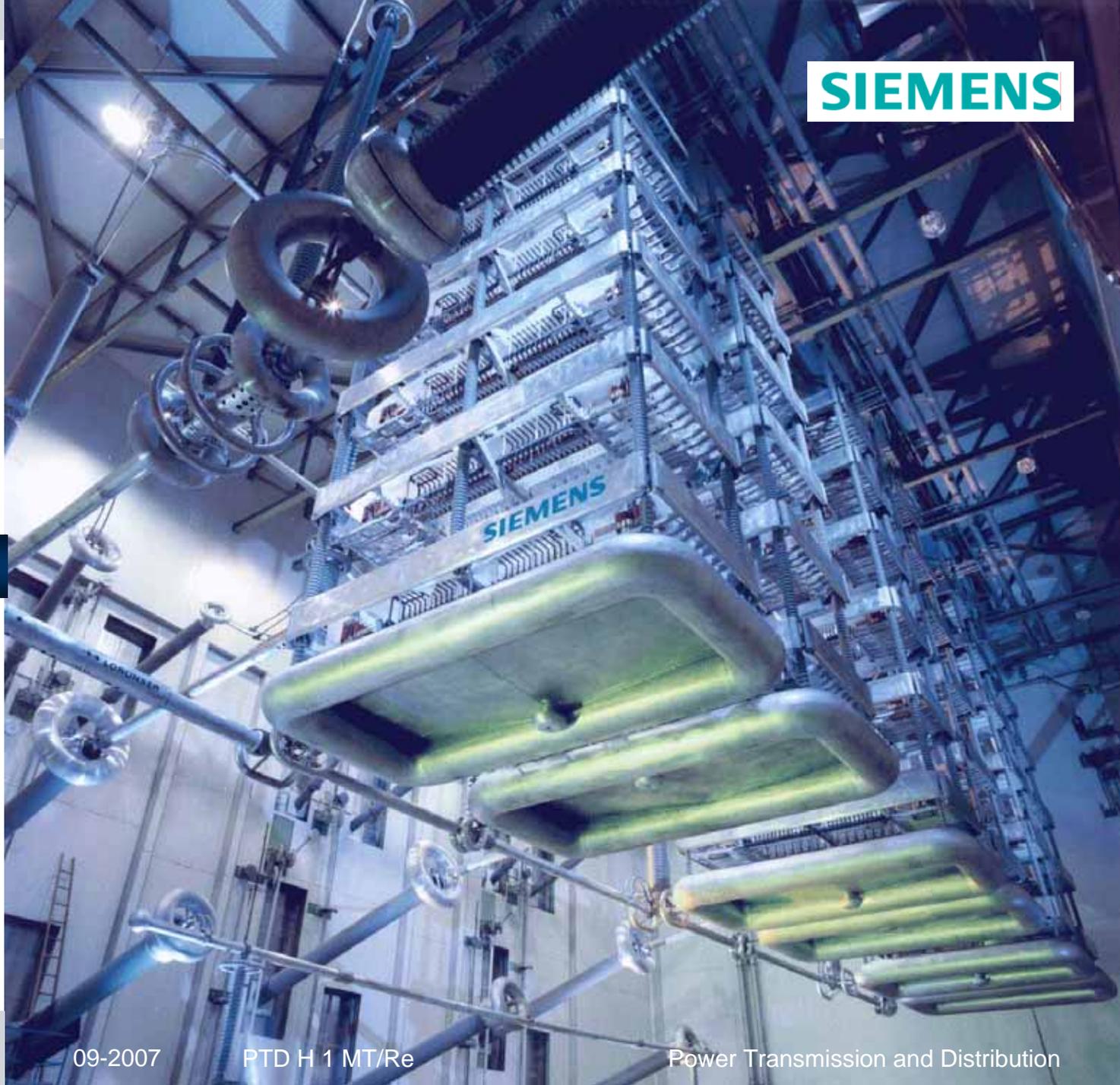


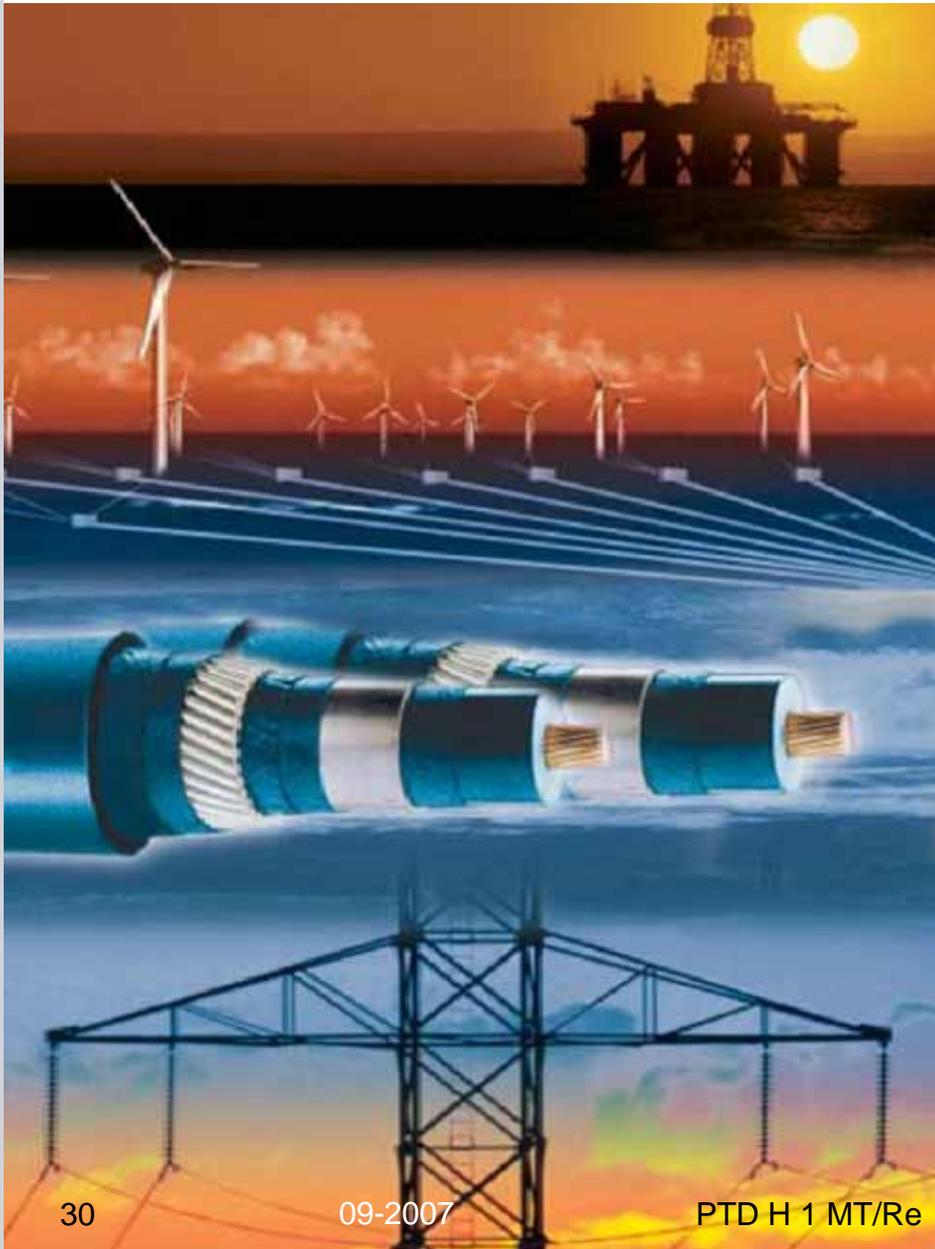
Dielectric Testing of Valve-Support Structure

Finally ...

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... it will look
like this:





HVDC

with VSC -

HVDC PLUS

HVDC PLUS – The Power Link Universal System

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- Low Switching Frequency
- Reduction in Losses
- Less Stresses



In Comparison with 2 and 3-Level Converter Technologies

... with Advanced VSC Technology

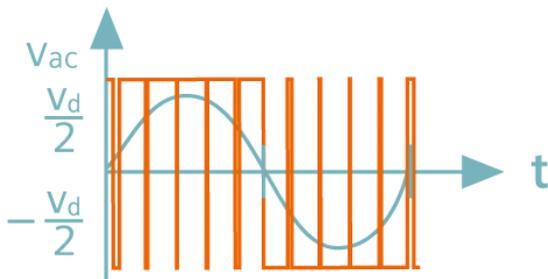
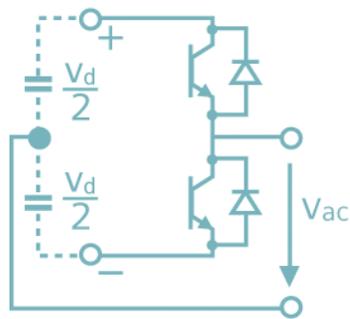
Siemens uses MMC Technology (Modular Multilevel Converter)



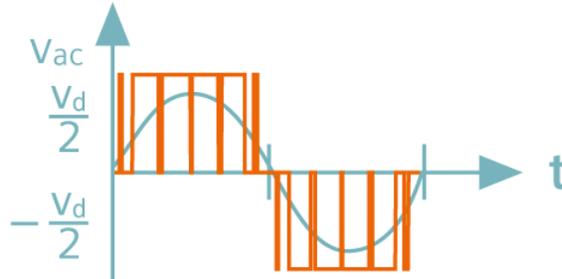
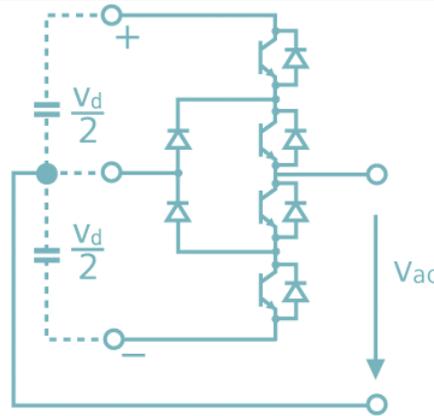
Clean Energy to Platforms & Islands ...

The Evolution of HVDC PLUS and VSC Technology

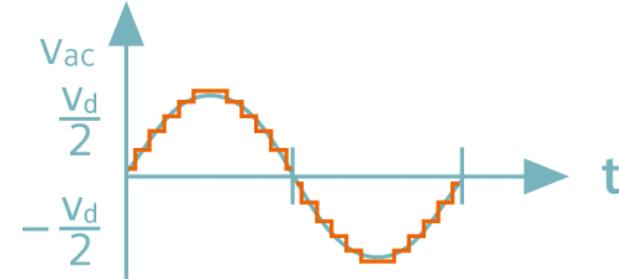
Topologies: Two-Level Three-Level Multilevel



GTO / IGCT

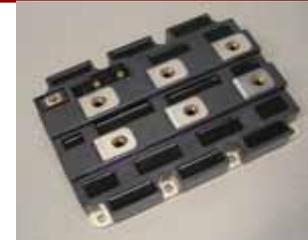
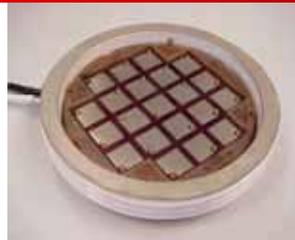


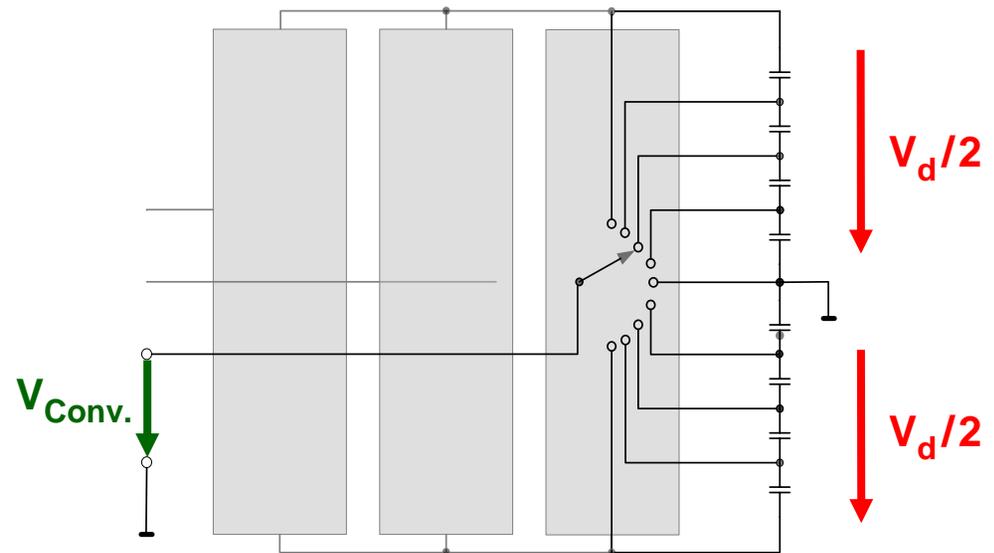
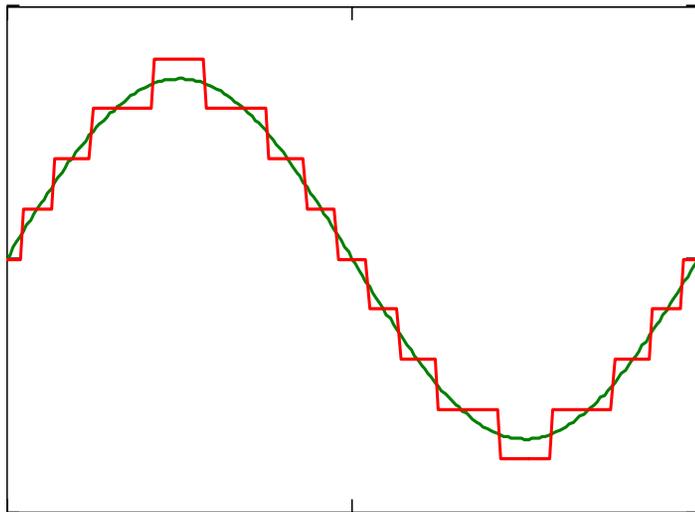
IGBT in PP



IGBT Module

Power Electronic Devices:

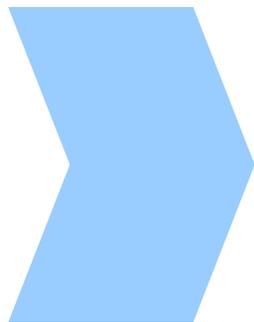
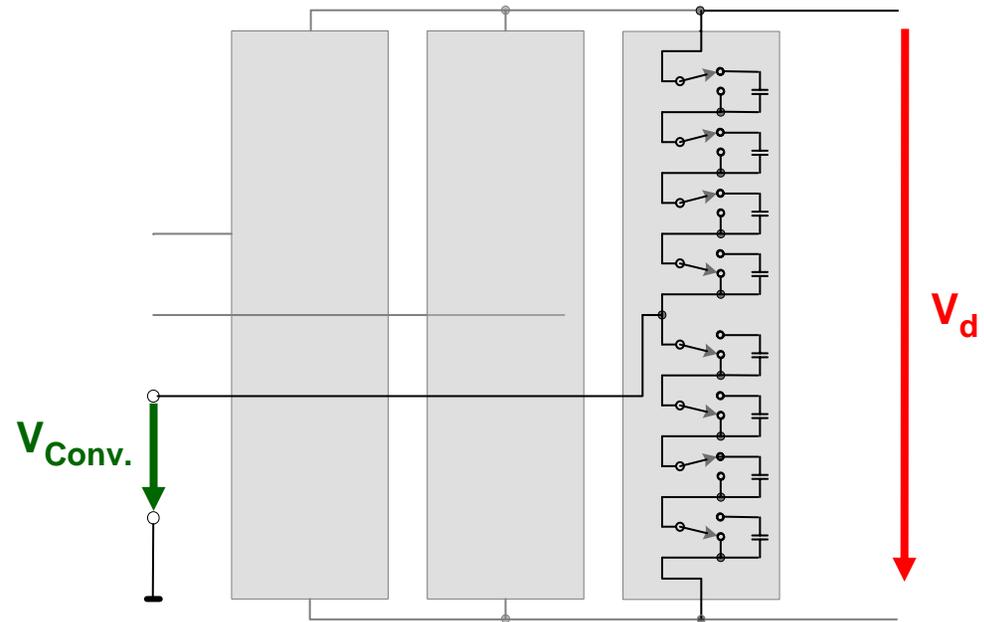
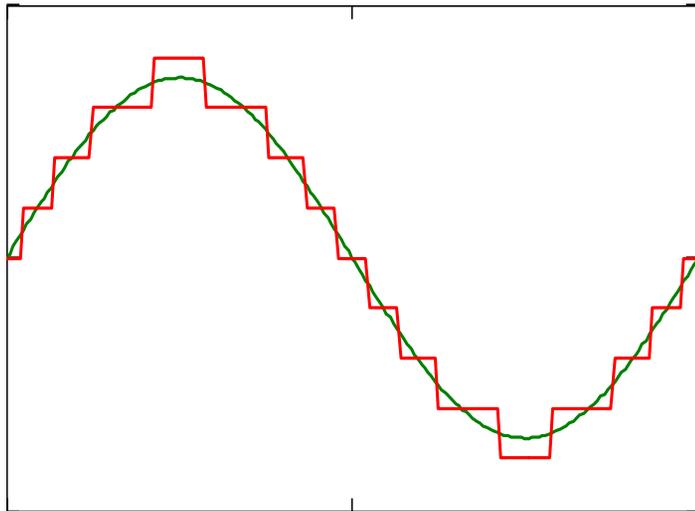




Small Converter AC Voltage Steps

Small Rate of Rise of Voltage

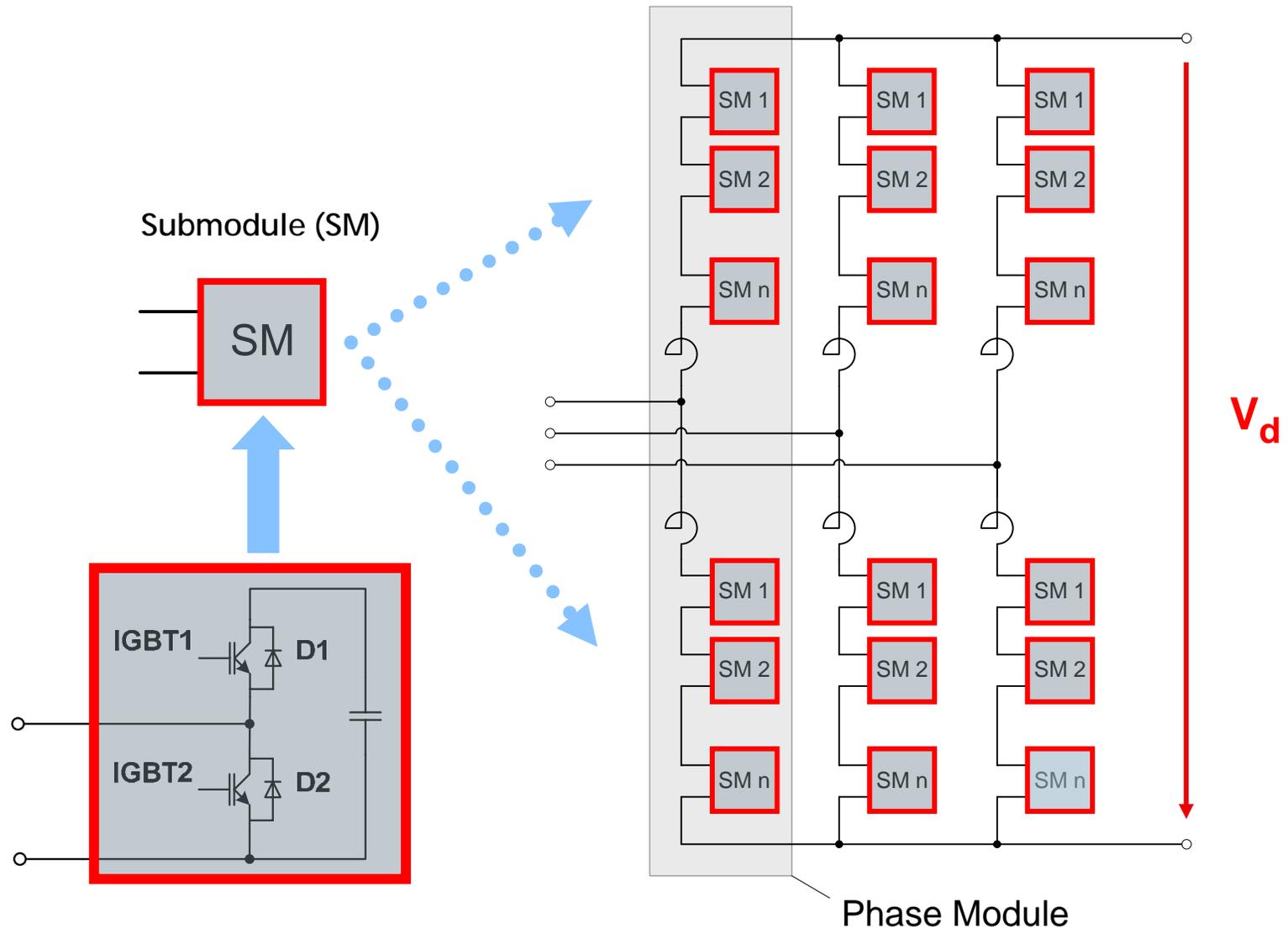
The **Advanced Multilevel** Approach: **MMC – Modular Multilevel Converter**



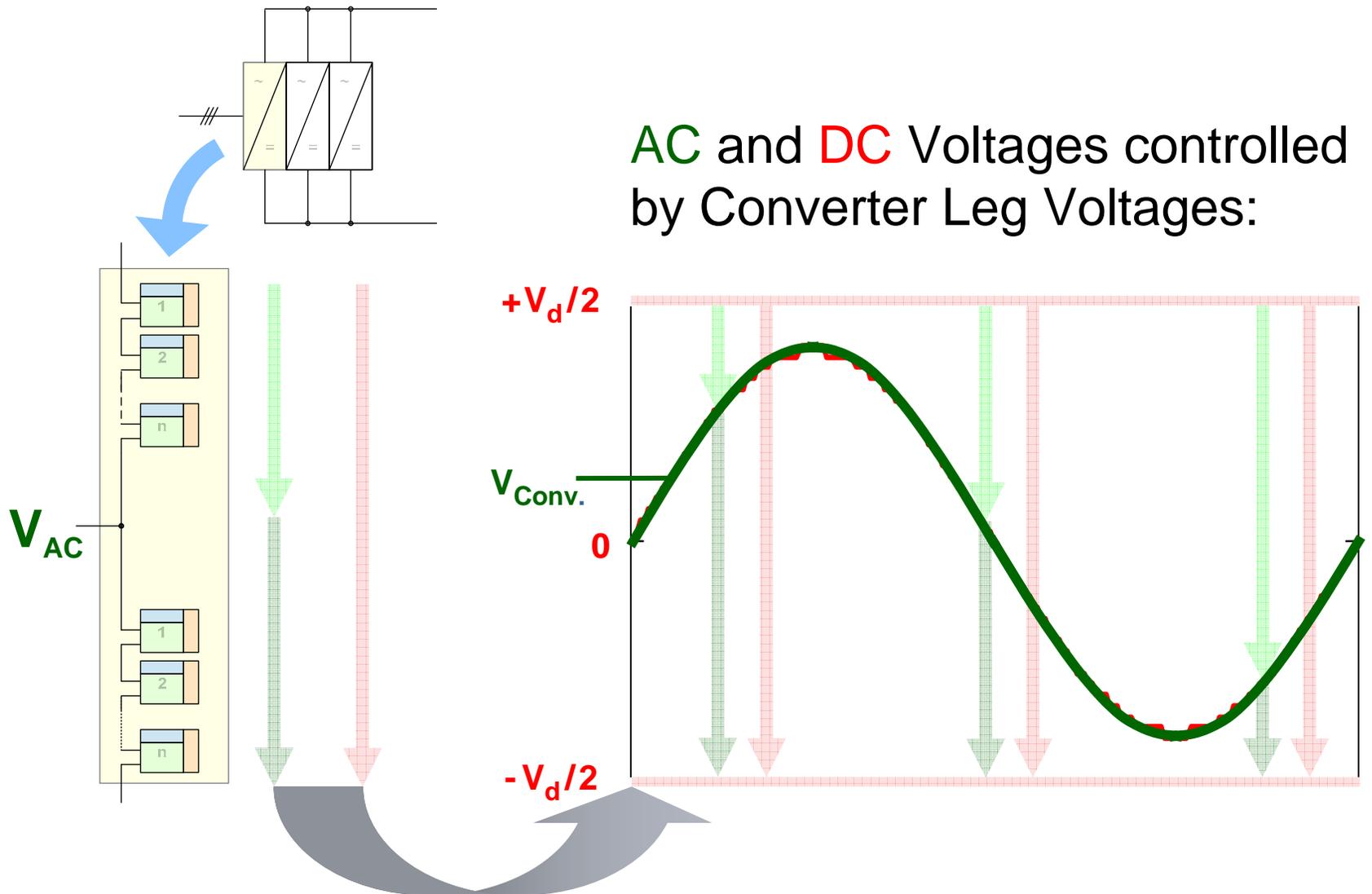
Low Generation of Harmonics

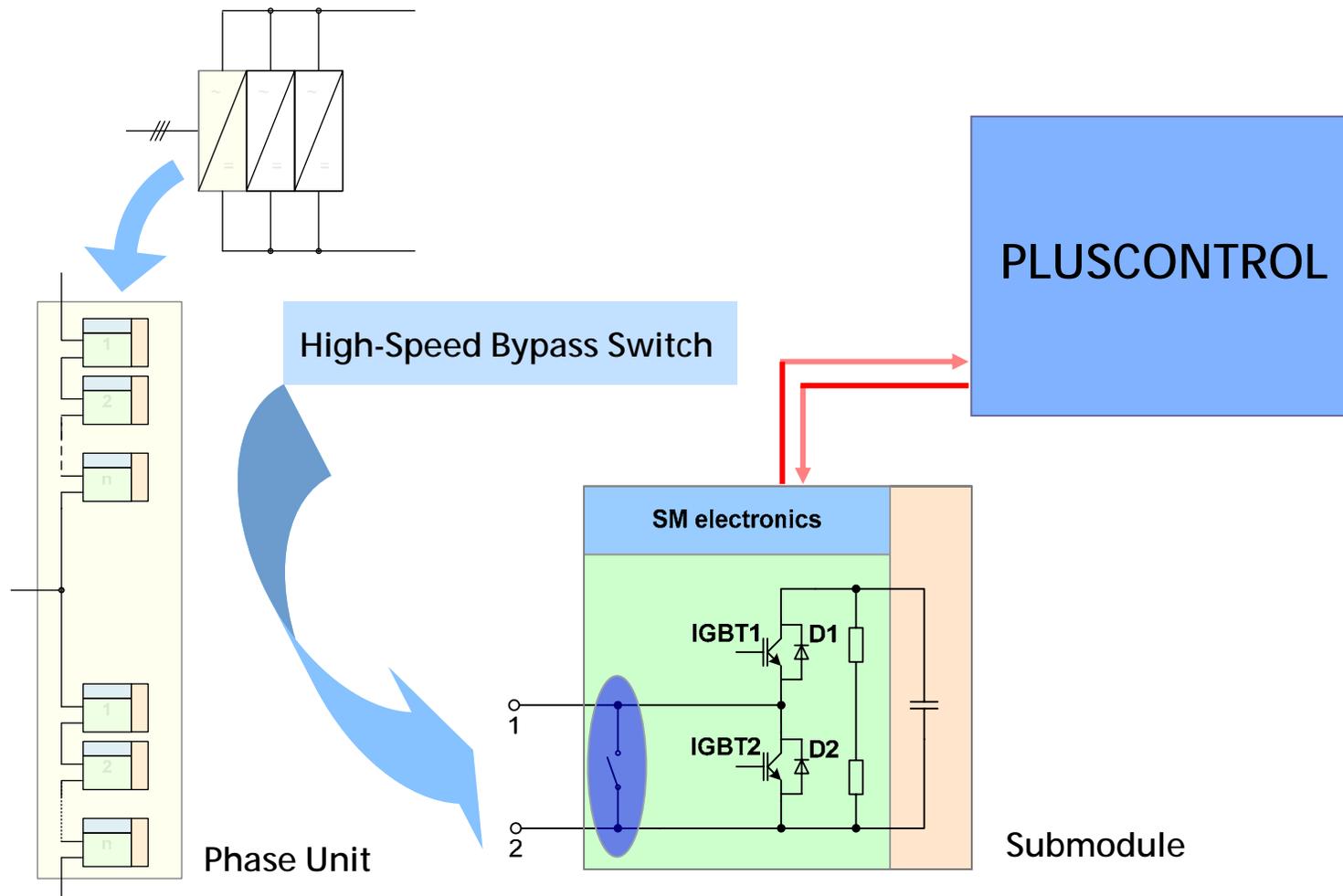
Low HF Noise

Low Switching Losses

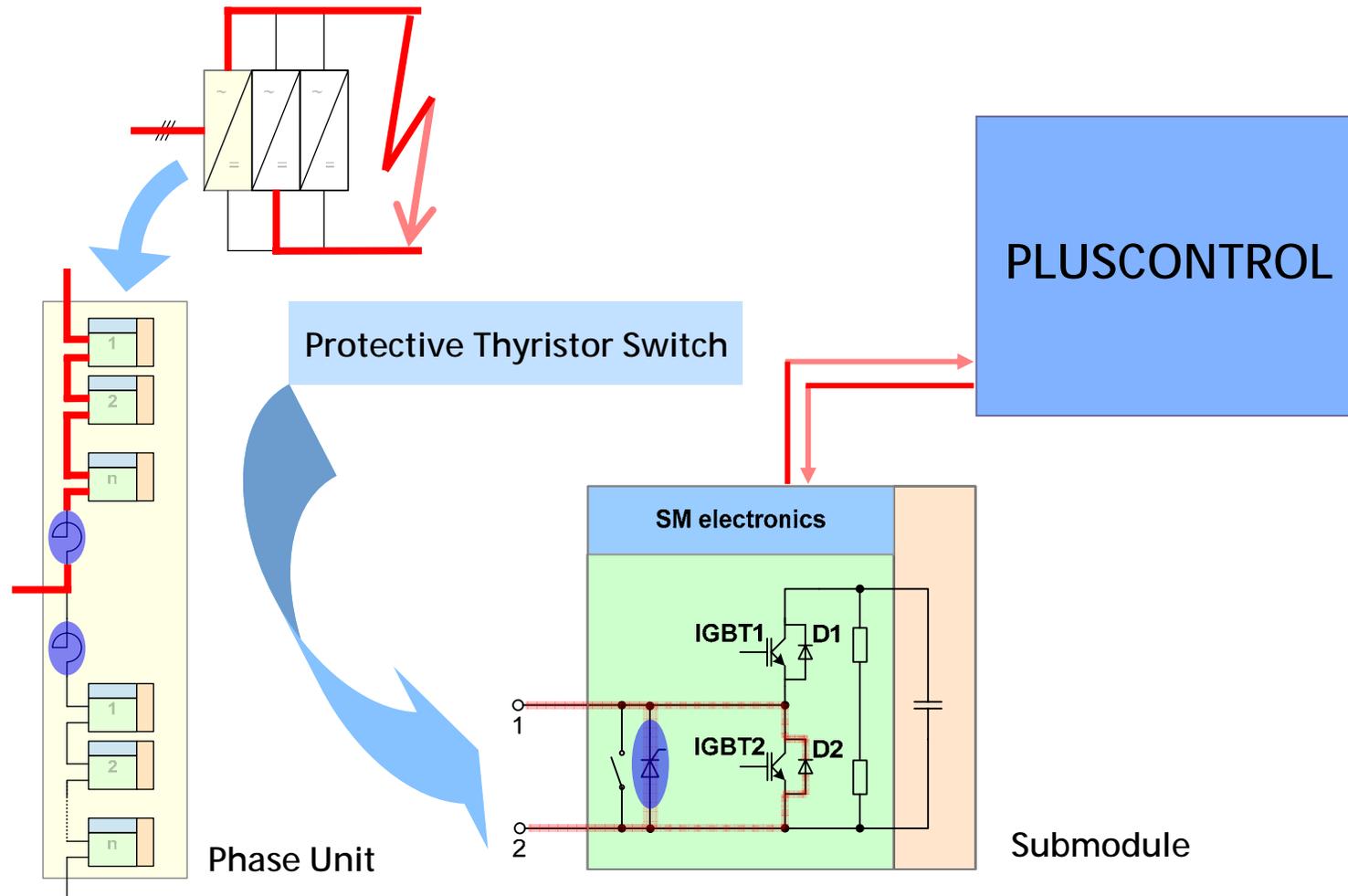


The Result: MMC – a perfect Voltage Generation SIEMENS

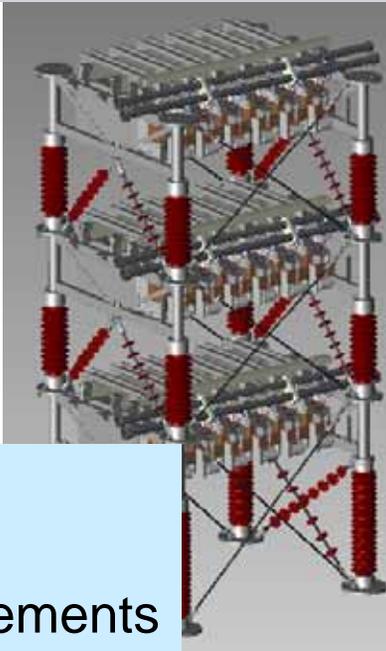




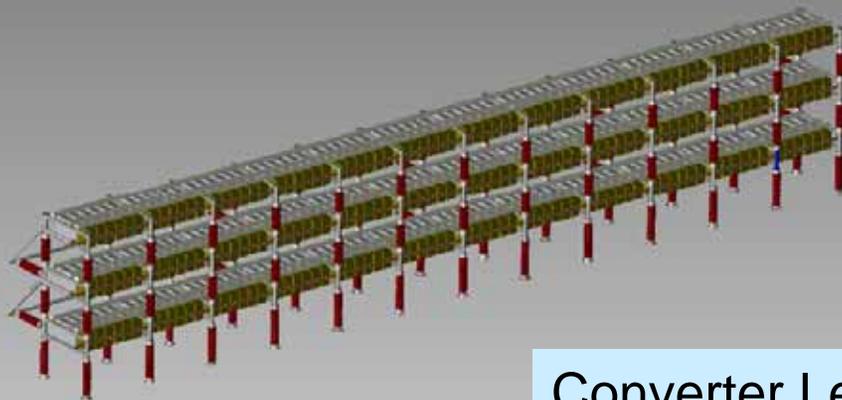
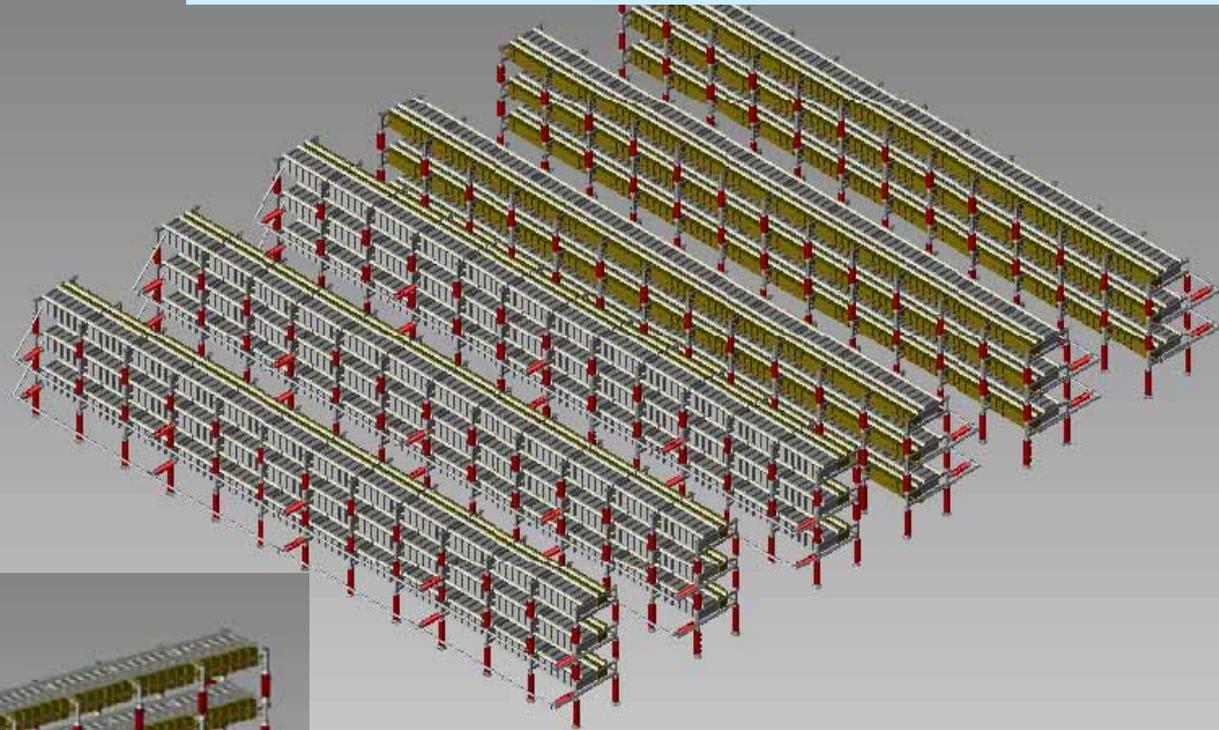
Fully suitable for **DC OHL** Application: **Line-to-Line Fault** – a crucial Issue



Typical Converter Arrangement for 400 MW



Optional Seismic Reinforcements



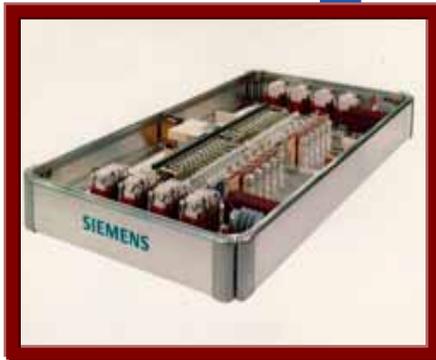
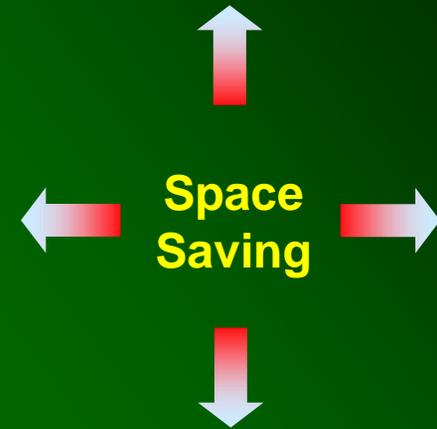
Converter Leg with more than 200 Submodules

Benefits of HVDC PLUS

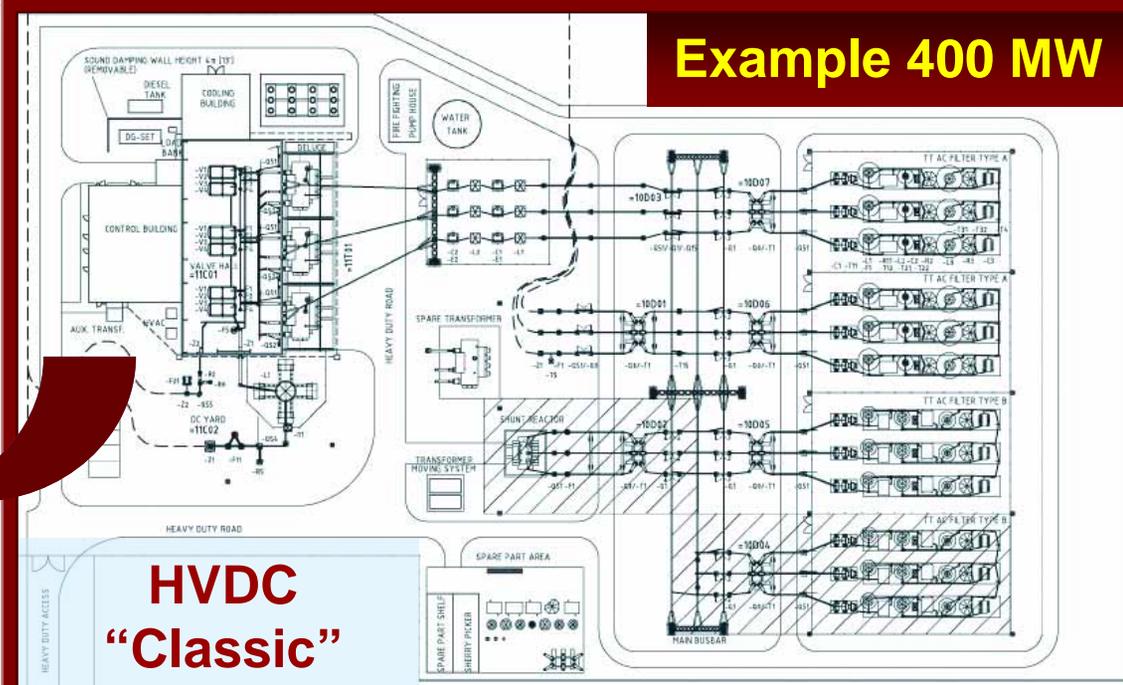
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HVDC PLUS



Example 400 MW



**HVDC
"Classic"**

Conclusions

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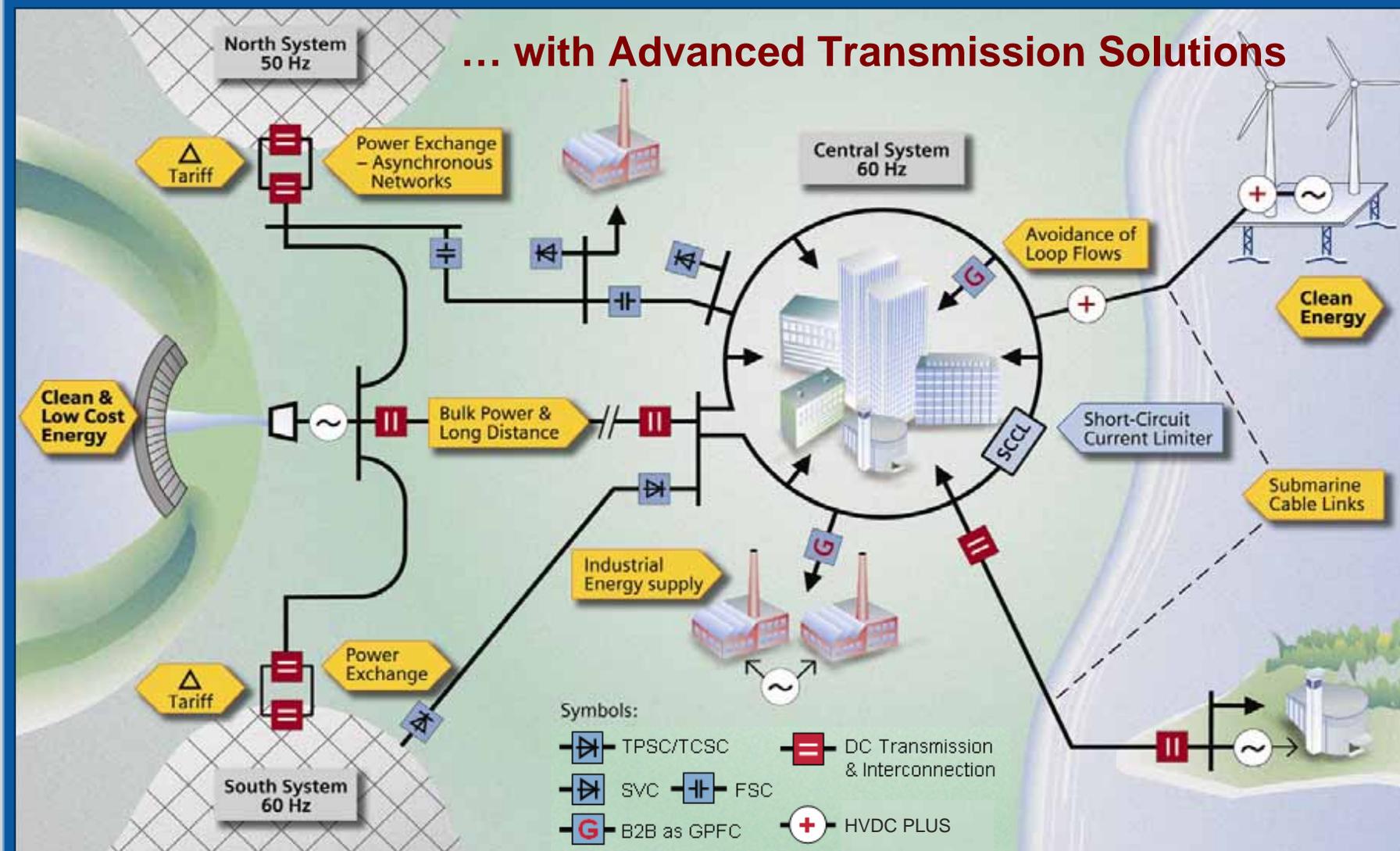
Transmission *needs ...*

Elimination of

Bottlenecks

*and Congestion by use of
Advanced Technologies*

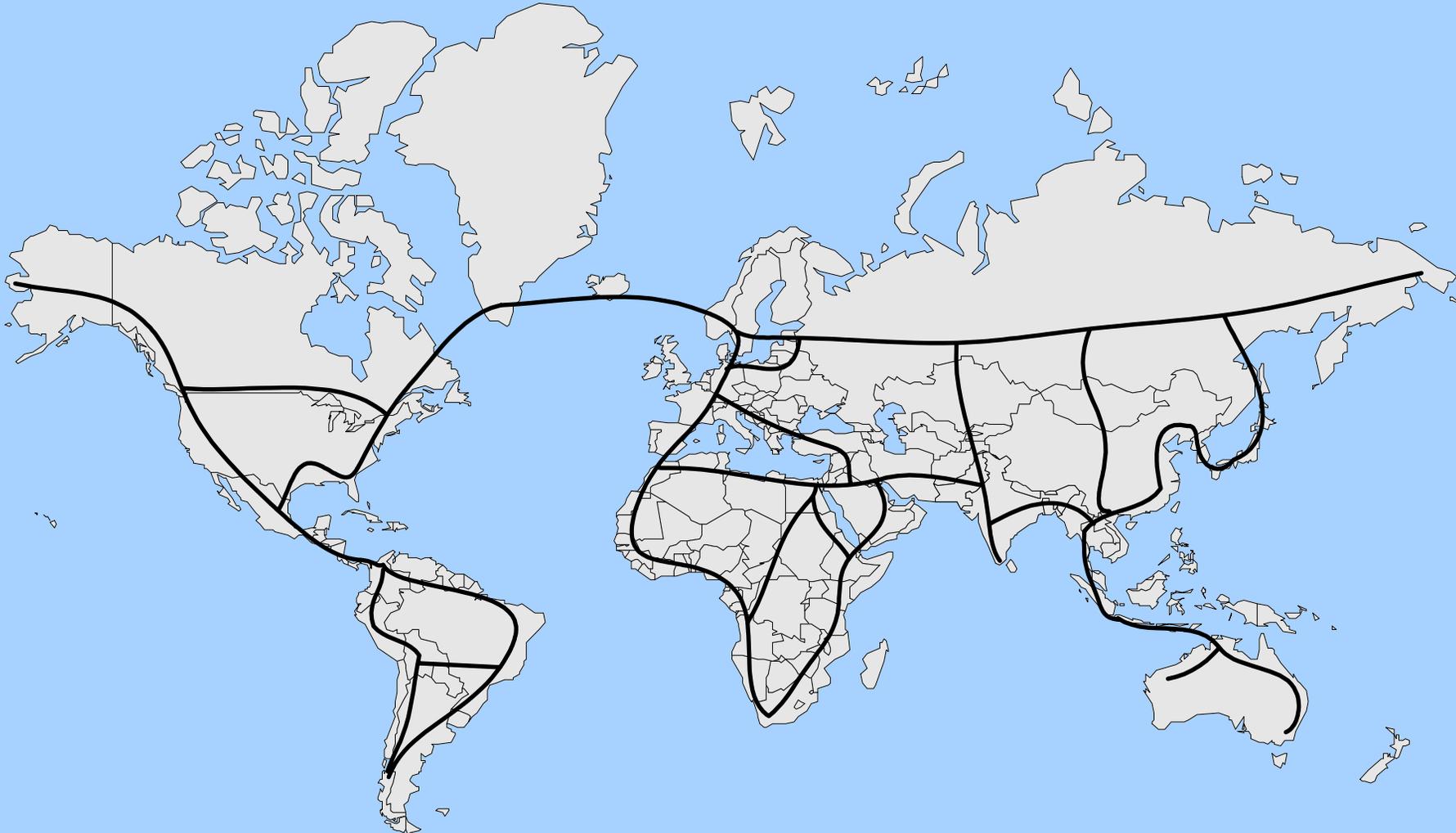
... with Advanced Transmission Solutions



The Future ? - Global Link for Green Energy

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with HVDC and FACTS



Siemens is successful in the HVDC Business –



for more than 30 Years

World's 1st VSC HVDC with MMC-Technology

World's 1st HVDC with LTT and integrated BOD

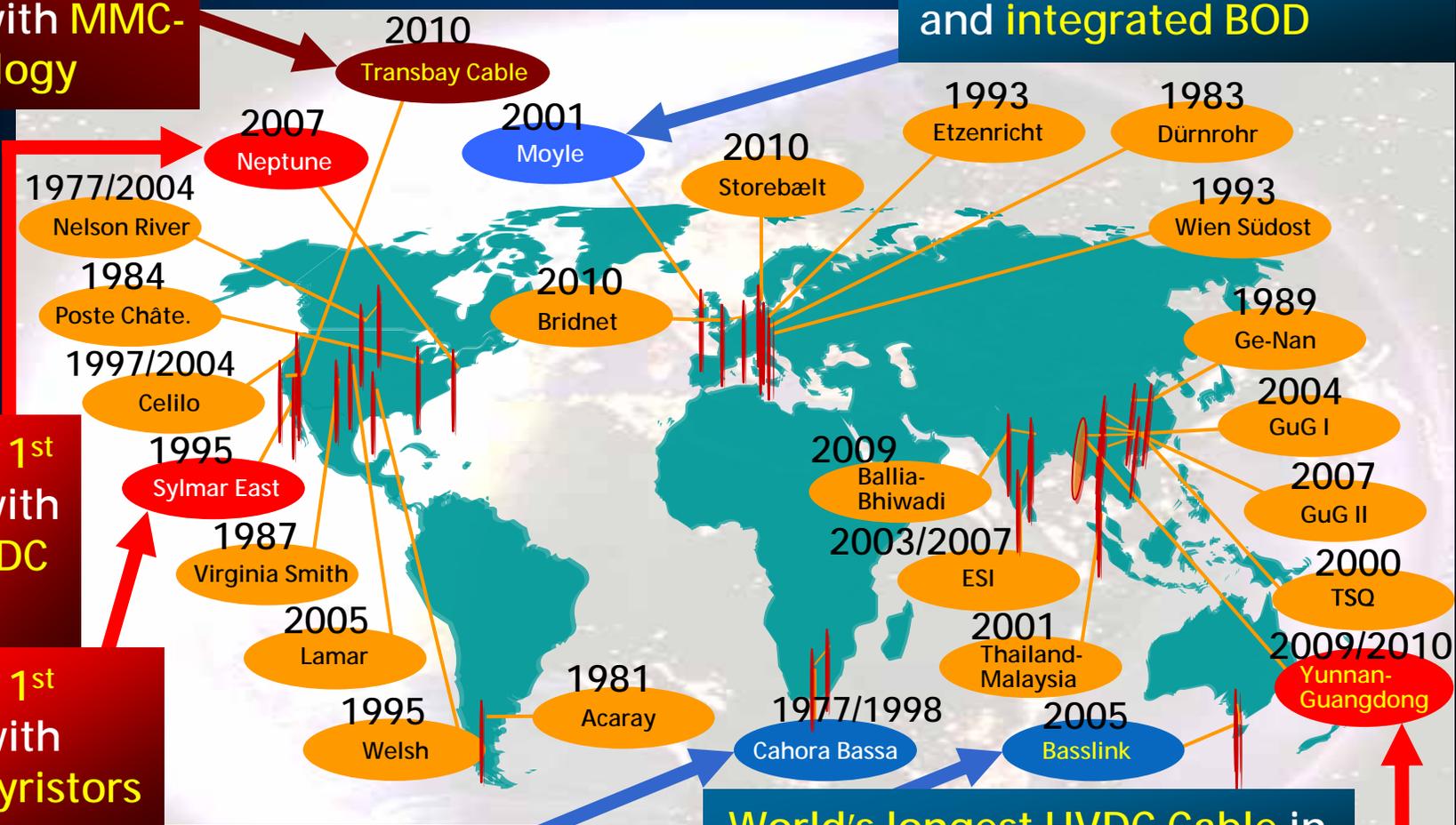
World's 1st HVDC with 500 kV DC Cable

World's 1st HVDC with 8 kV Thyristors

World's 1st HVDC with Transmission Voltage above 500 kV

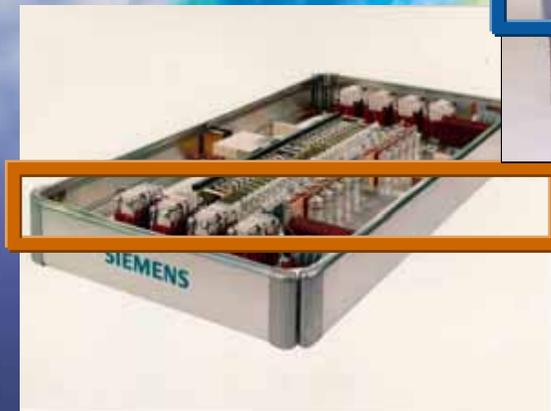
World's longest HVDC Cable in Operation

World's 1st HVDC with Transmission Voltage of 800 kV !



with **HVDC** &
FACTS from
Siemens

Now available –
with **VSC PLUS**
Technology



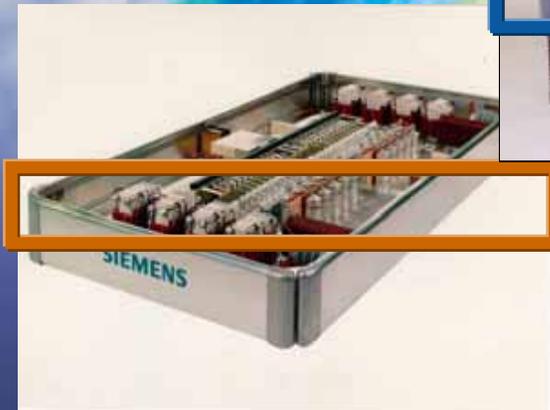
HVDC PLUS
and **SVC PLUS**

... and the Lights
will keep shining !

Sustainability &

Security of

Supply



Thank You for
your Attention !