Perspectives of HVDC and FACTS for System Enhancement and Grid Interconnection

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Power Transmission Systems are the essential for Power Markets

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Investments in Power Industry

Generation | **Transmission** | **Distribution**

~ 40 %

can be

or

-neck

~ 20 %

Depending on Grid Structure

~ 40 %

Megatrends
Demographic Change and Urbanization

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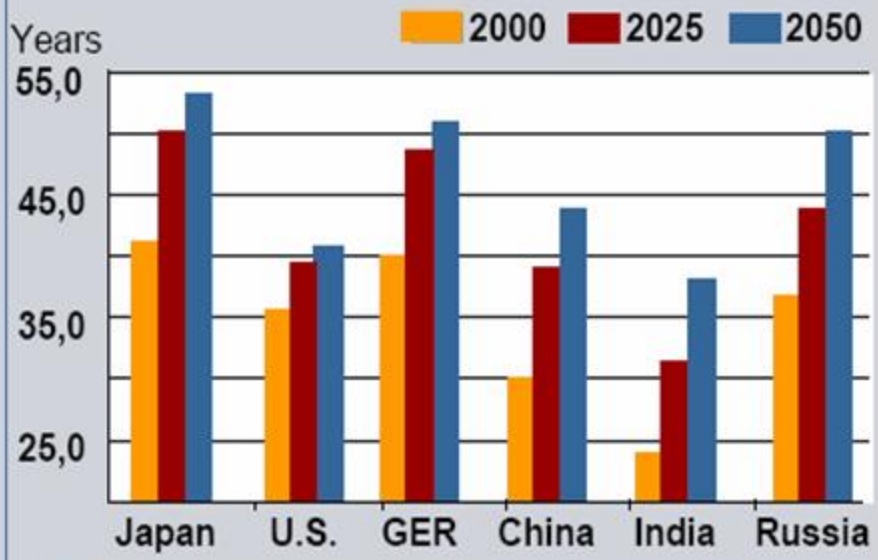
Demographic Change

Development average age in selected countries



- Growing world population:
  2003: 6,3 bn. 2015: 7,2 bn.
  2025: 7.9 bn. 2050: 8,9 bn.
- 2050: For the first time, number of people >60 years equals number of people <15 years

Urbanization

Growth of 12 largest cities (Source: UN)

- Growth of world population Ø 1% p.a.
- Growth of urban population Ø 1,8% p.a.

Increasing Power Demand ... and changing Energy Resources

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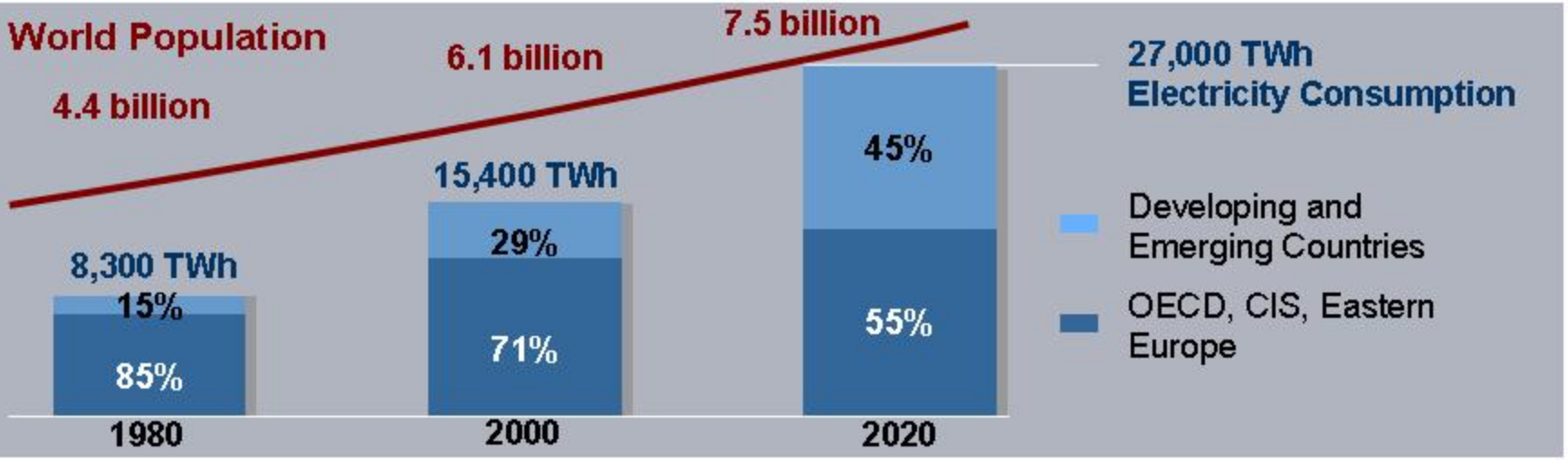

Lifetime assuming static Consumption

Conventional Oil
Non conventional Oil
Conventional Gas
Non conventional Gas
Coal
Uranium

Lifetime (proven Reserves)

45 Years
20 Y
65 Years
0 Years
200 Years
100 Years

Lifetime (Reserves + Resources)

70 Years
30-80 Years
150 Years
600 Years
1300 Years
>1000 Years with Recycling

Sources: Siemens IEA, UN, Siemens PG GS4, 2006

Different challenges for Power Transmission and Distribution

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energy consumption per capita

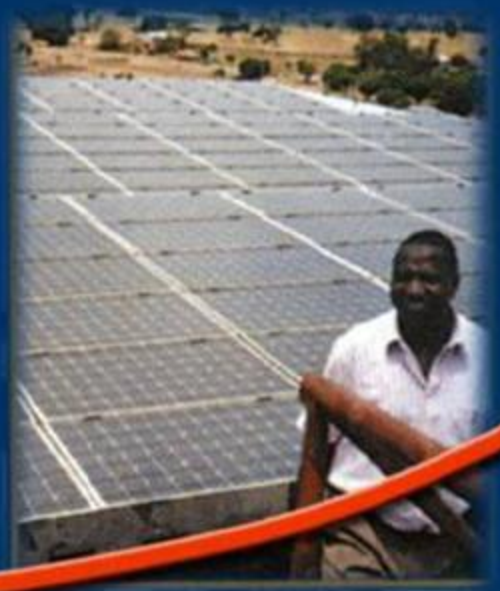
small isolated grids

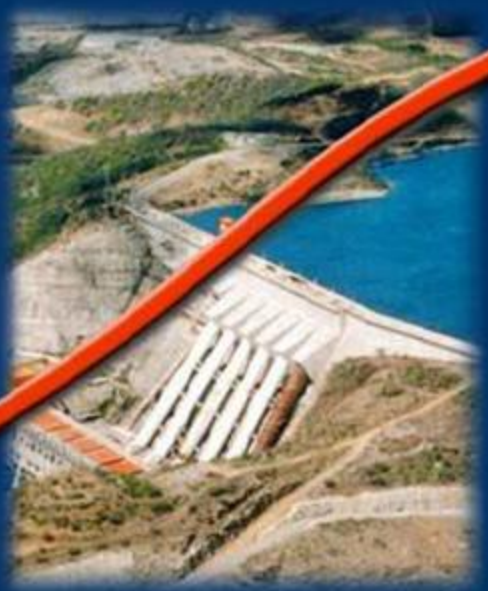
higher voltage levels

long distance transmission

transmission shortages

demand for clean energy and high quality





developing countries

emerging countries

industrialized countries

Challenges for Electrical Power Transmission and Distribution

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Need for more Energy

Urbanization

Scarcity of Natural Resources

Environmental Awareness

Open Markets

Increased Use of Distributed and Renewable Energy Resources

Capacity Increase and Bulk Power Transmission over long Distances

Distribution within congested Areas / Megacities

Goal: reliable, flexible, safe and secure Grids

If Power Flow exceeds the Design Criteria: Blackout

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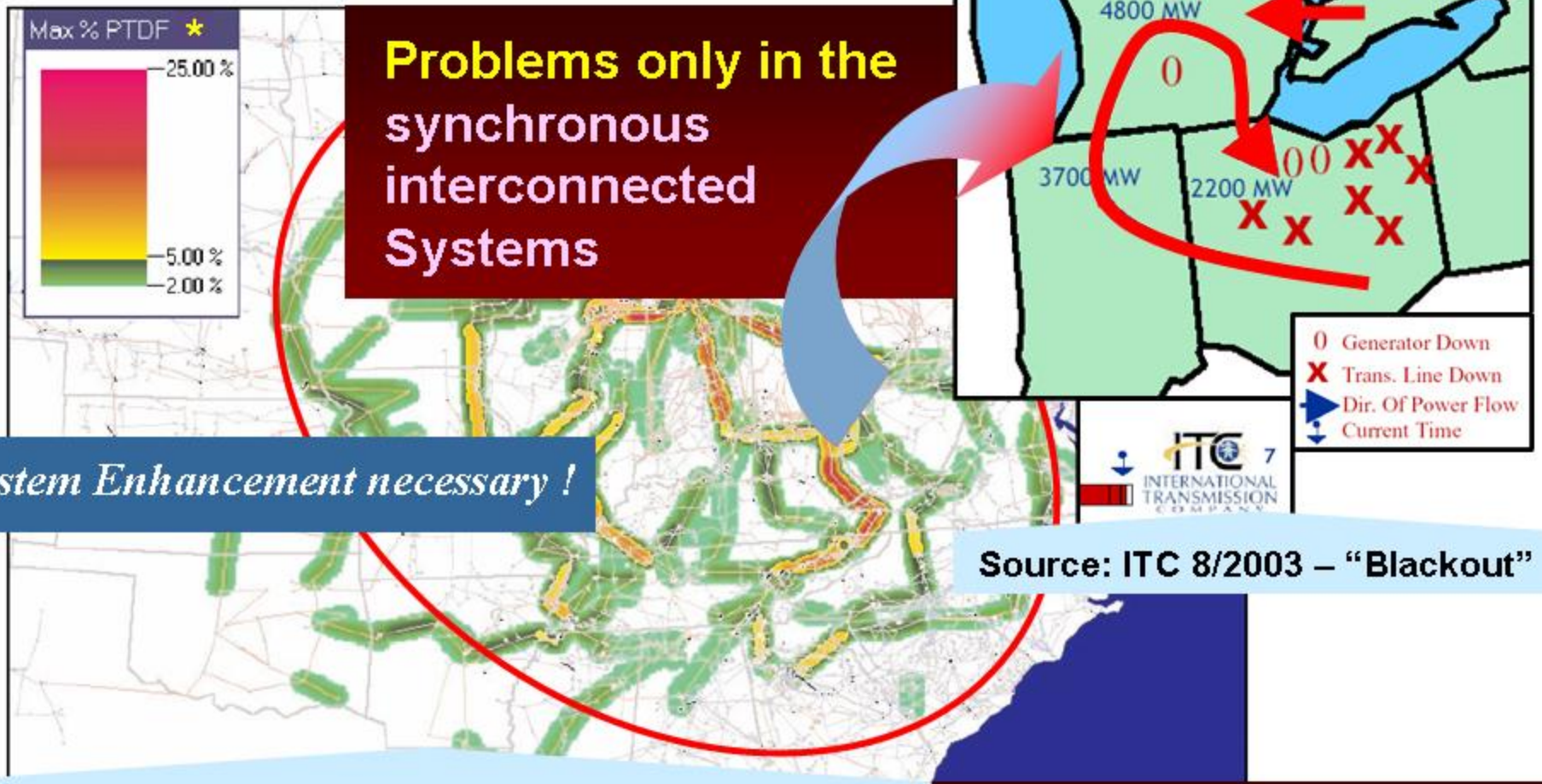
Figure 3: Loop Flow of Power Transfer from Wisconsin to TVA



System Enhancement necessary !

Source: ITC 8/2003 – "Blackout"

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

Development of DC Transmission: Worldwide installed Capacity

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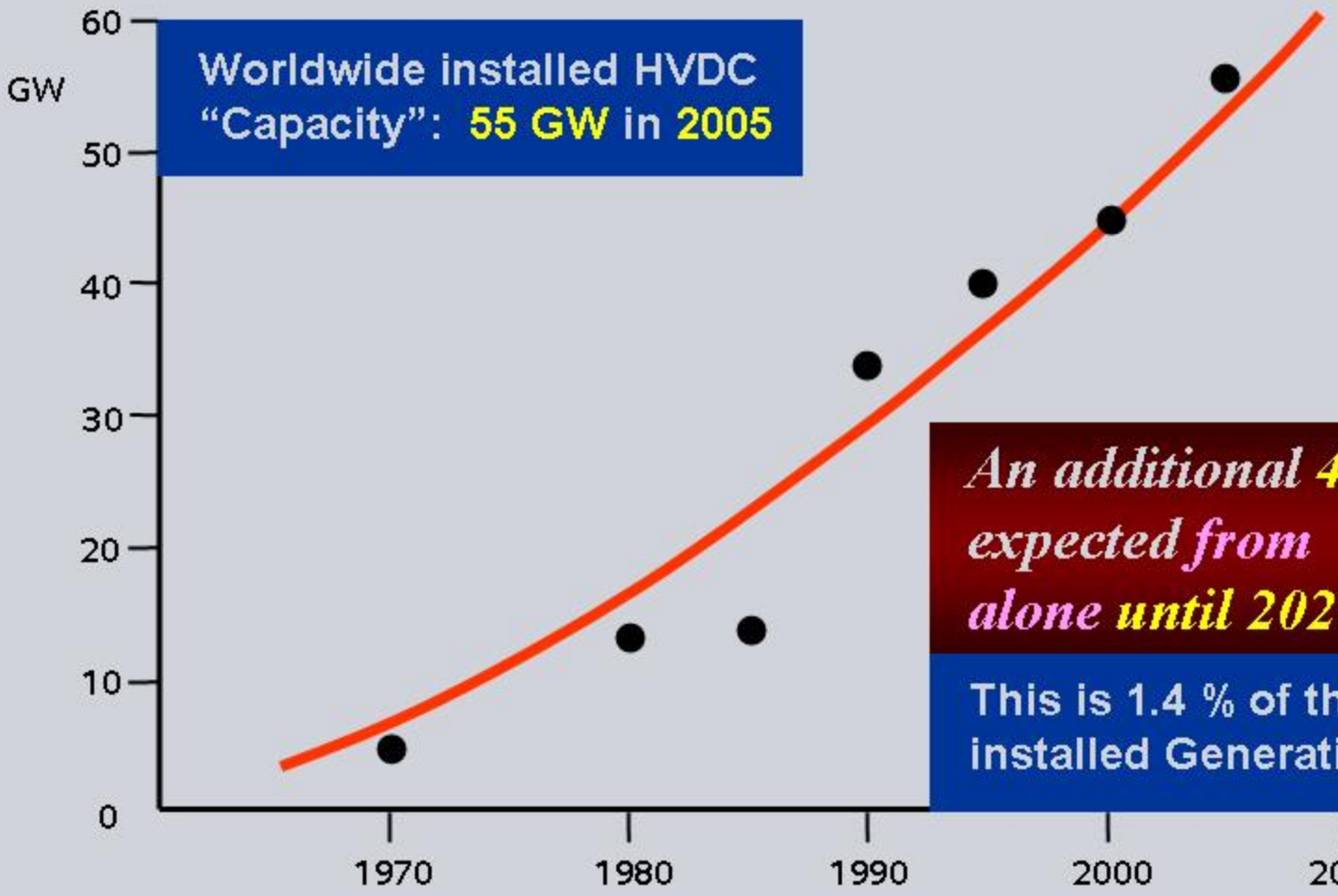

Sources: IEEE T&D Committee 2000 - Cigre WG B4-04 2003

Hydro Power
Long Distance Transmission Tian-Guang

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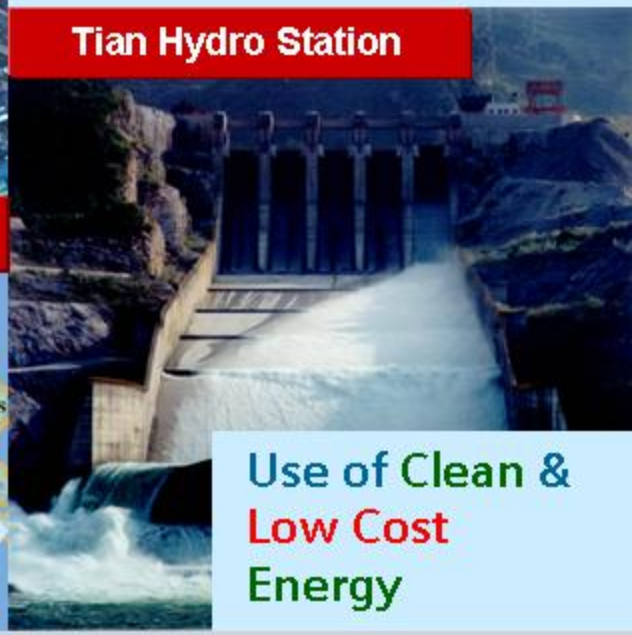
The Task: Connection of Hydro Generation to Remote Load Centers

- **Operated by:**
  South China Electric Power JVC (SCEP)
- **System Data:**

Rating	1,800 MW
Voltage	+/-500 kVDC
Thyristor	8 kV
Line Length	960 km



Benefits

Use of Clean & Low Cost Energy

Europe - HVDC Moyle Interconnector

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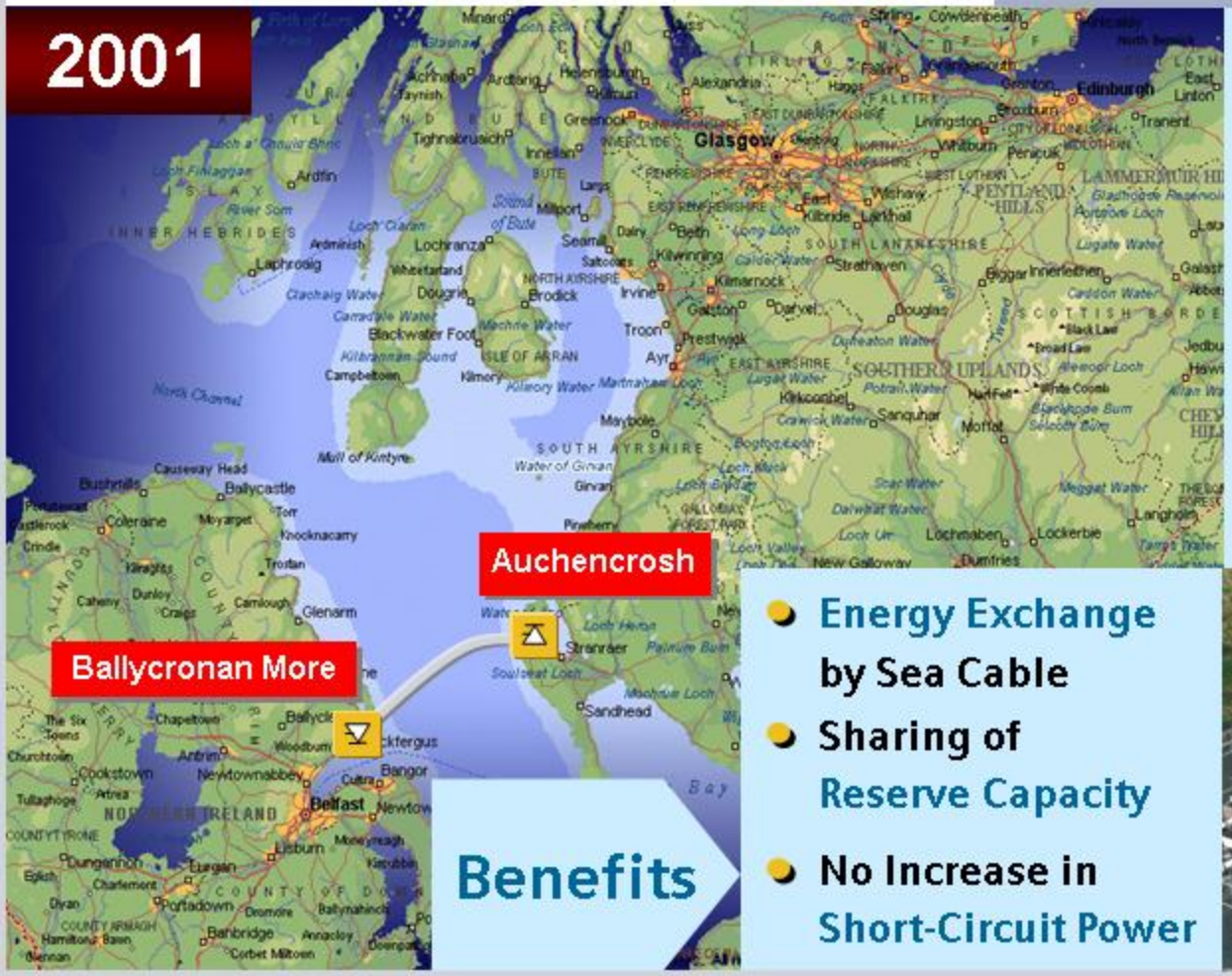
The Task:
Sea-Cable Transmission

World's first HVDC with LTT and wafer-integrated BOD



- **Operated by:**
  Moyle Interconnector Ltd., Northern Ireland
- **System Data:**

Rating	2x250 MW
Voltage	250 kV DC
Thyristor	8 kV LTT
Cable Length	64 km

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

via HVDC submarine Cable into the Megacity New York

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= secure and reliable power supply for congested and densely populated area with minimum right of way requirement

Duffy Avenue /
Long Island – New York

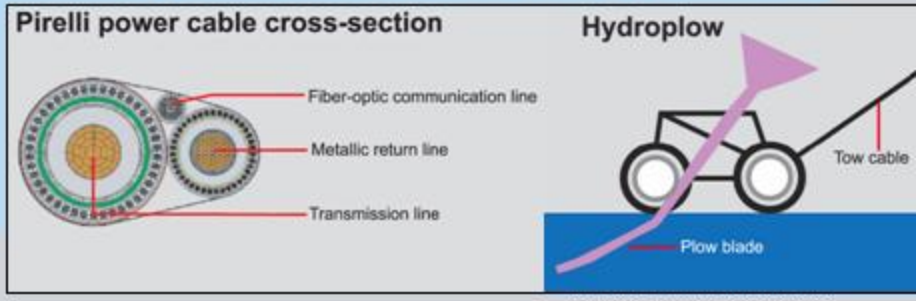
Atlantic Ocean

Converter Station

Off-Island Cable Route

Sayreville / New Jersey

Data:
660MW at 500kV DC, 104km Cable



Now: Why UHV AC & DC ?

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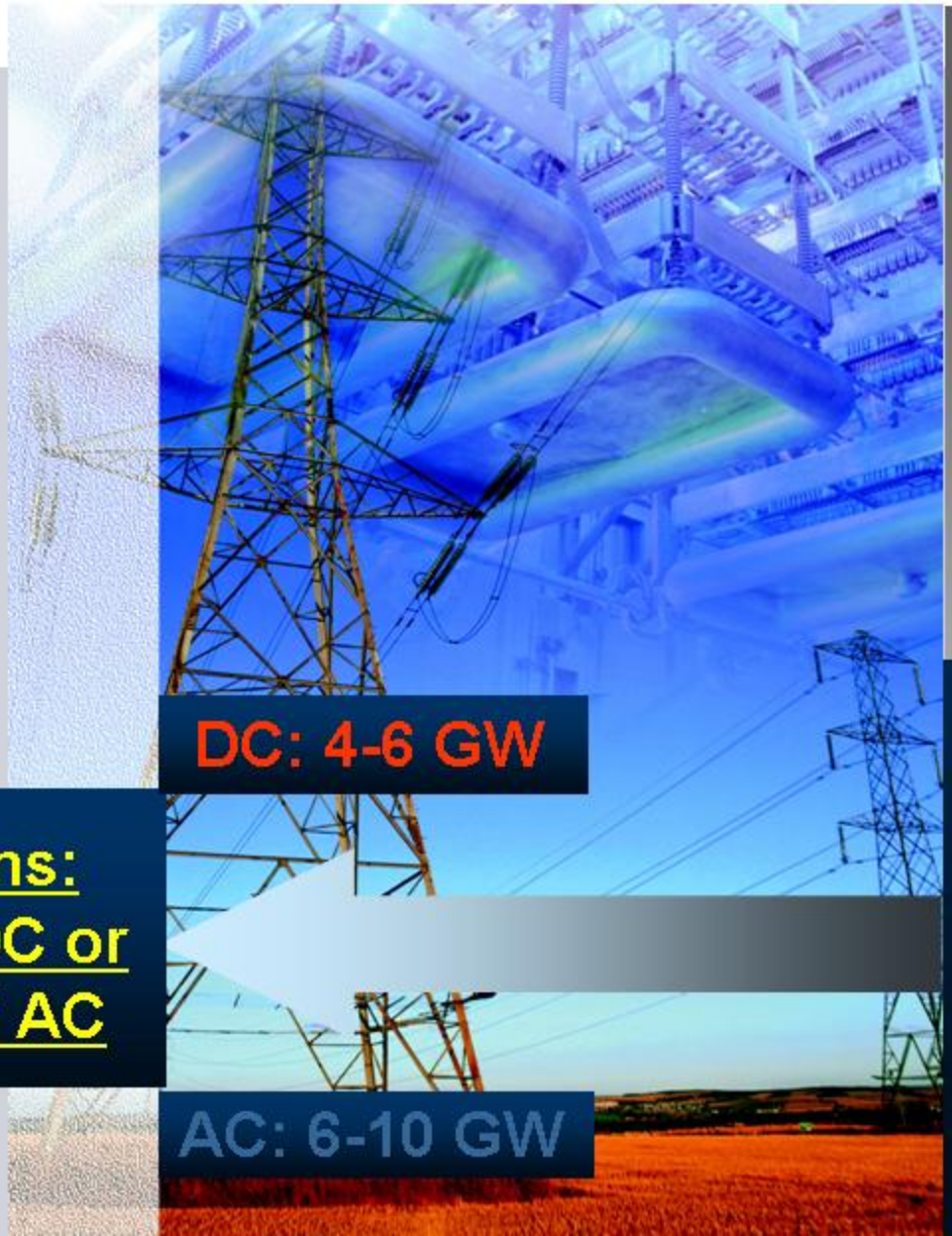

Some Countries will need **Bulk Power Transmission Corridors ...**

Solutions:
800 kV DC or
1000 kV AC

Costs* of High-Voltage LD-Transmission …

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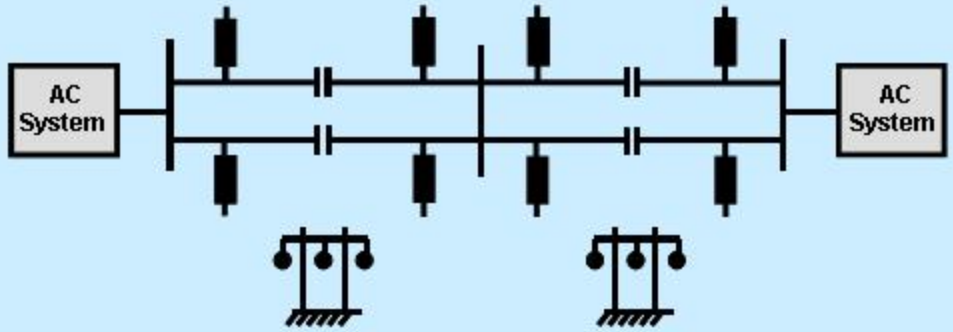
… for Point-to-Point Connection

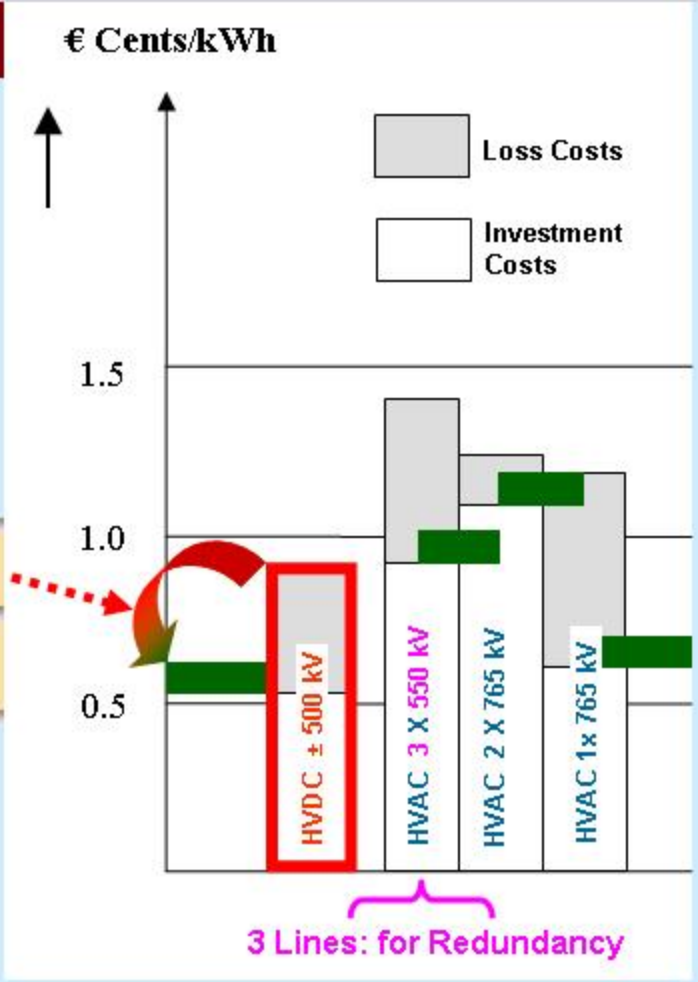
HVAC



61 % Loss Cost & CO_2 Reduction with 800 KV DC

HVDC

* & Sustainability



For Comparison: Reduction in Losses with 800 kV DC

Source: Siemens PTD SE PTI - 2002

AC versus DC – Right of Way a View of the Tower Geometry

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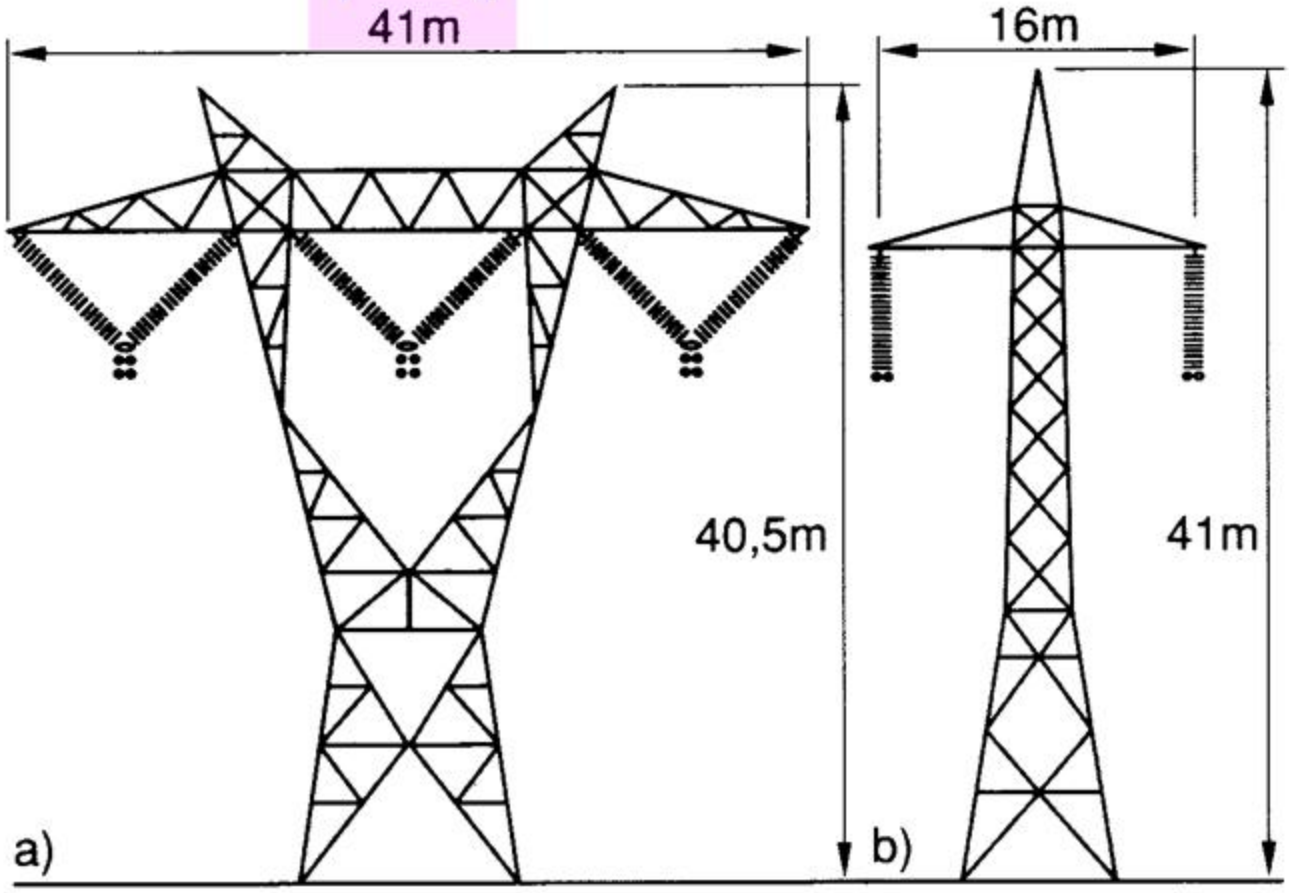
Comparison of Towers for 500 kV AC Line a) and ± 500 kV DC Line b), at same Transmission Capacity

3,000 MW

For Redundancy - 2 Lines: x 2



AC versus DC - Right of Way

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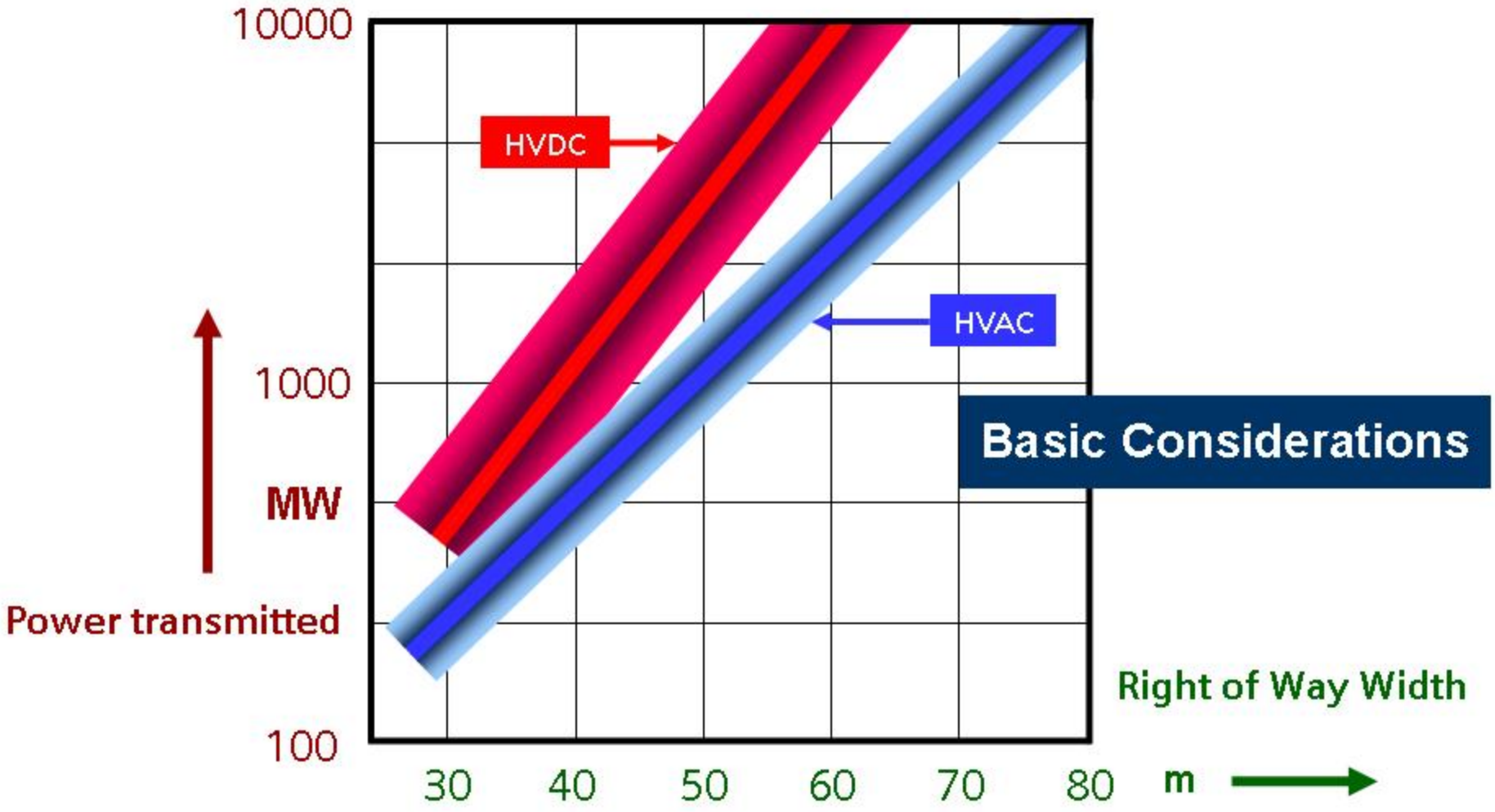
Comparison of Economic Transmission Power as a Function of Right of Way Width for HVDC and HVAC



Source: Siemens PTD SE PTI - 2002

DC versus AC: Break-Even Distance

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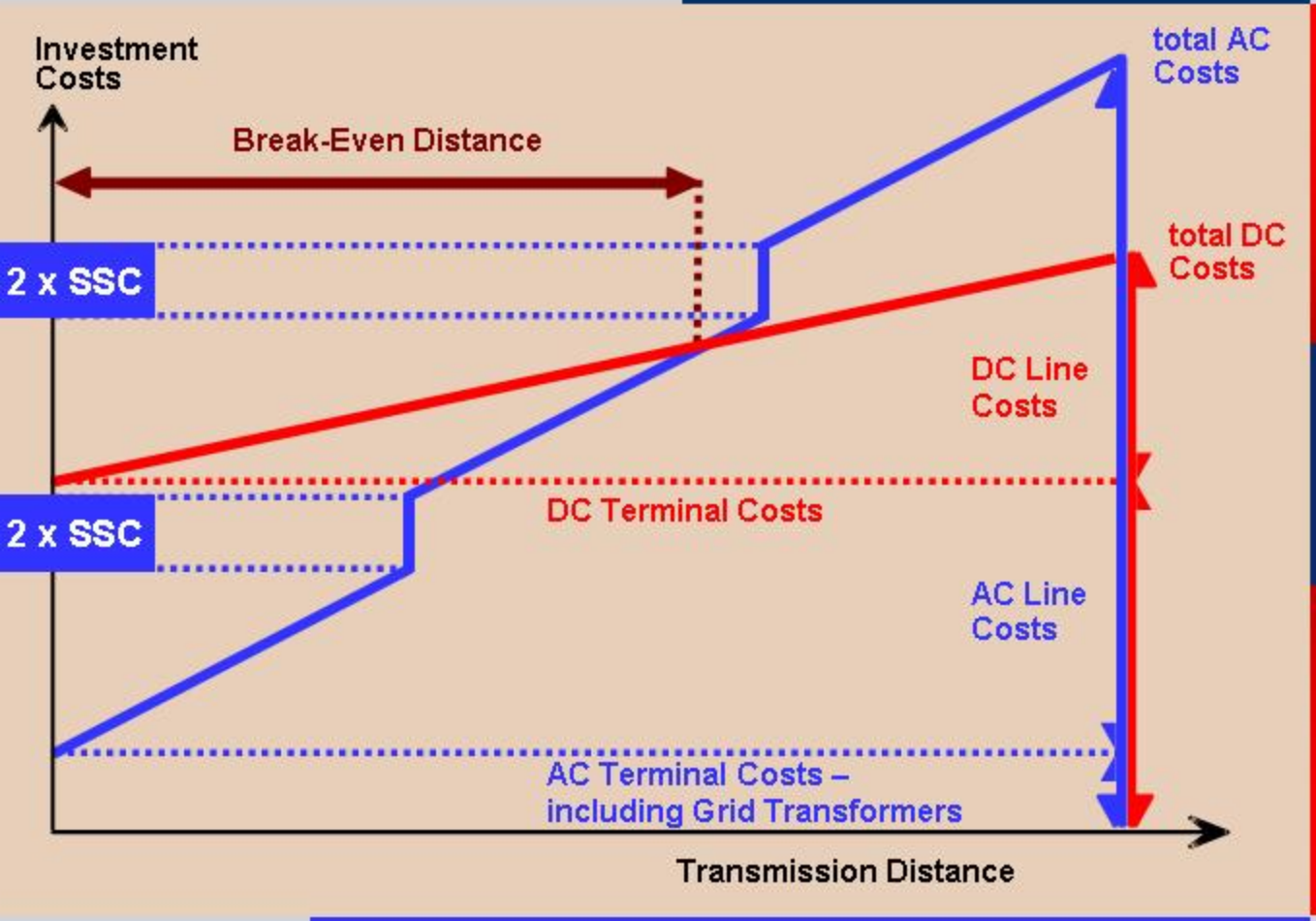
Basic Considerations



AC-DC Break-Even Distance:

~ 1,000 MW / 700 km

However, if:

$f_1 \neq f_2$

the Break-Even Distance is:

Zero km

SSC = Series & Shunt Compensation of AC Lines - required for each Section of the Line

Enhanced Efficiency:
HVDC East-South Interconnector and Ballia Bhiwadi

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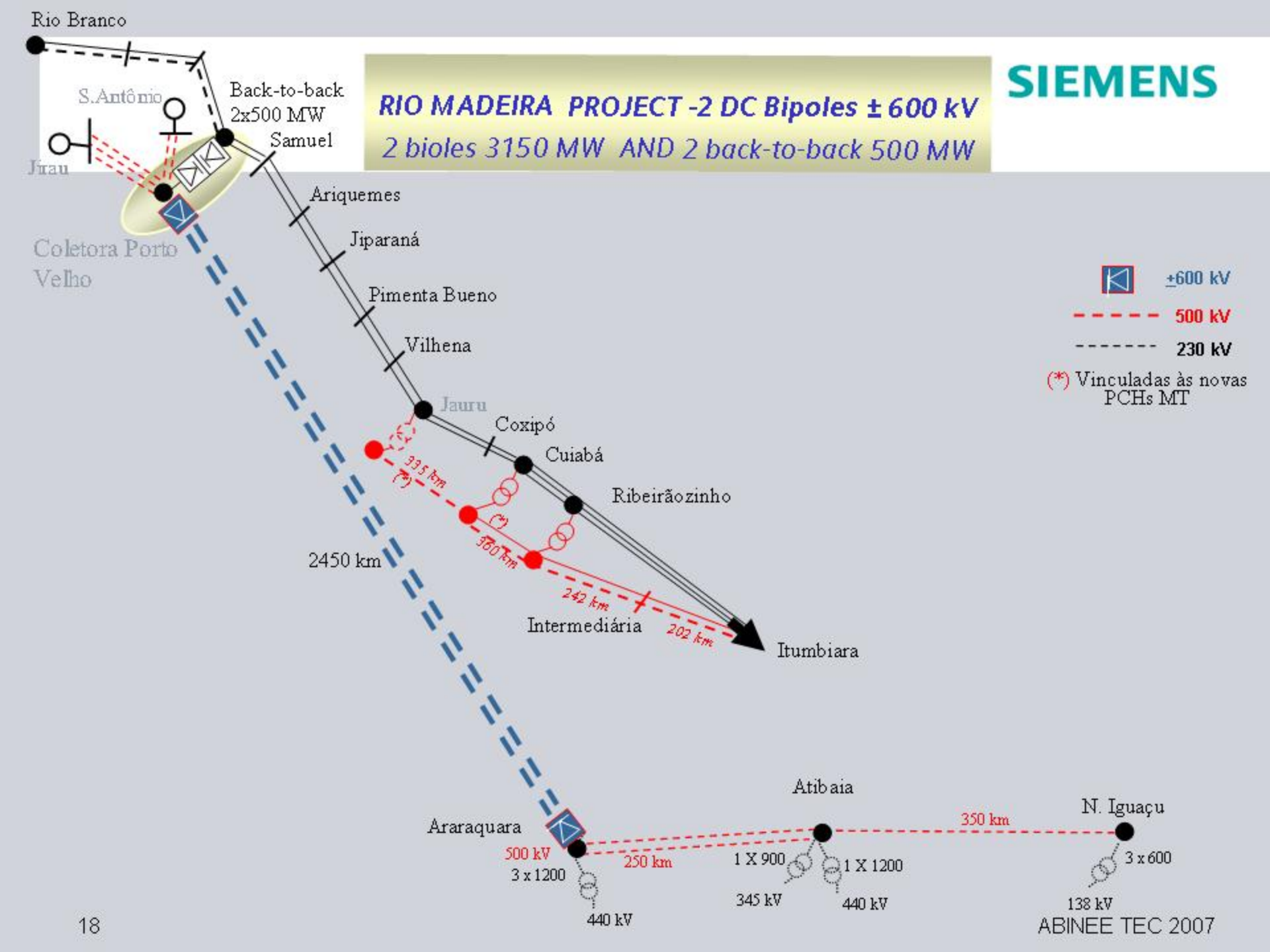
DC versus AC

2 x 3-ph AC 400 kV

1 x +/- 500 kV

Example of HVDC Ballia-Bhiwadi:

Reduction in CO_2: 688,000 tons p.a. through 37% less Transmission losses


Rio Branco
S.Antônio
Back-to-back
2x500 MW
Samuel
Jirau
RIO MADEIRA PROJECT -2 DC Bipoles ± 600 kV
2 bioles 3150 MW AND 2 back-to-back 500 MW
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Ariquemes
Jiparaná
Pimenta Bueno
Vilhena
Coletora Porto Velho
Jauru
Coxipó
Cuiabá
Ribeirãozinho
2450 km
335 km
(*)
360 km
242 km
202 km
Intermediária
Itumbiara
±600 kV
500 kV
230 kV
(*) Vinculadas às novas PCHs MT
Araraquara
500 kV
3 x 1200
440 kV
250 km
Atibaia
1 X 900
345 kV
1 X 1200
440 kV
350 km
N. Iguaçu
3 x 600
138 kV

Example China: Long Distances between Generation and Load Center (500 ~ 2,000 km)

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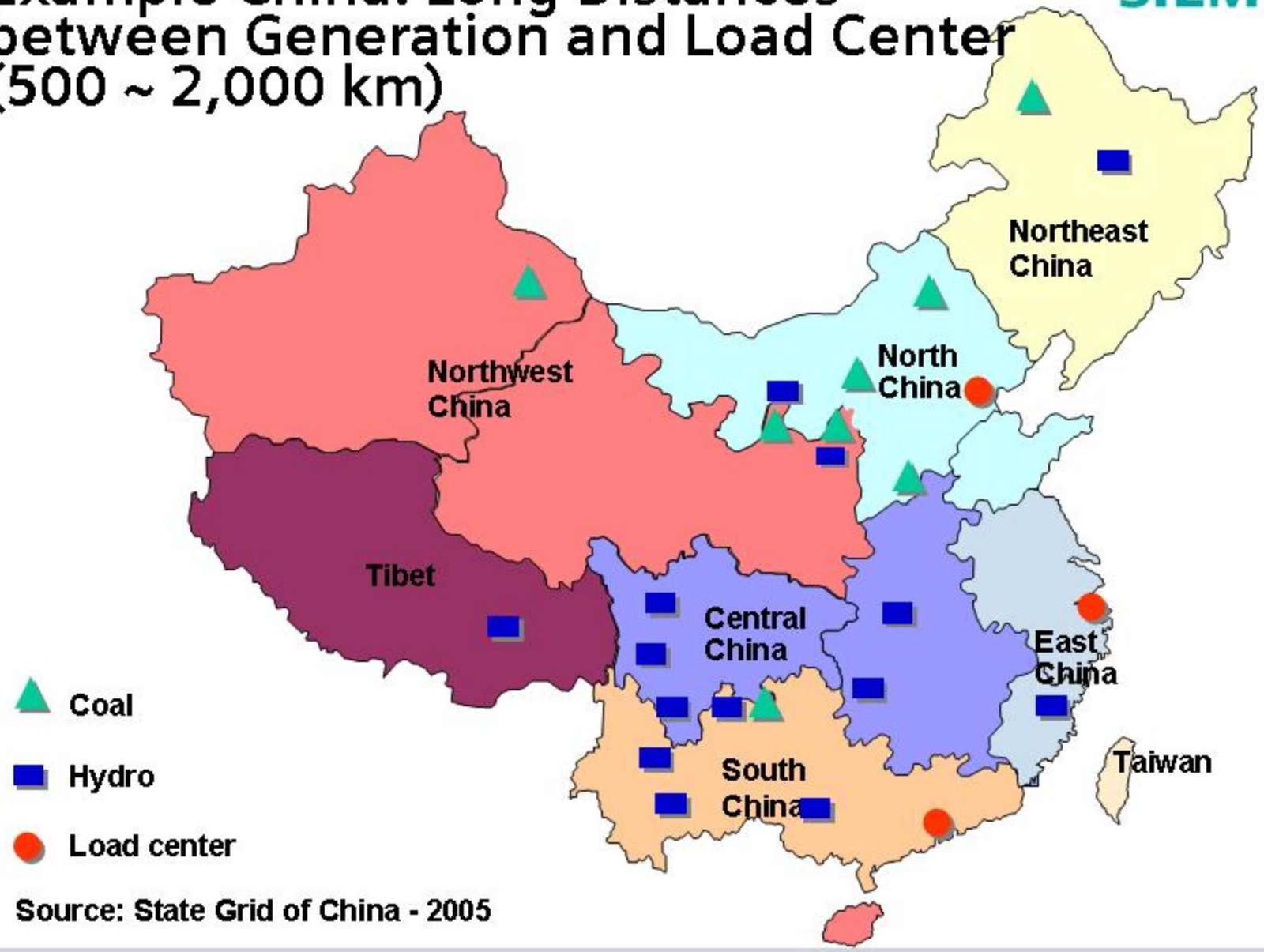

The Solution: AC & DC Power Transmission from West to East - Three Bulk Power Transmission Corridors

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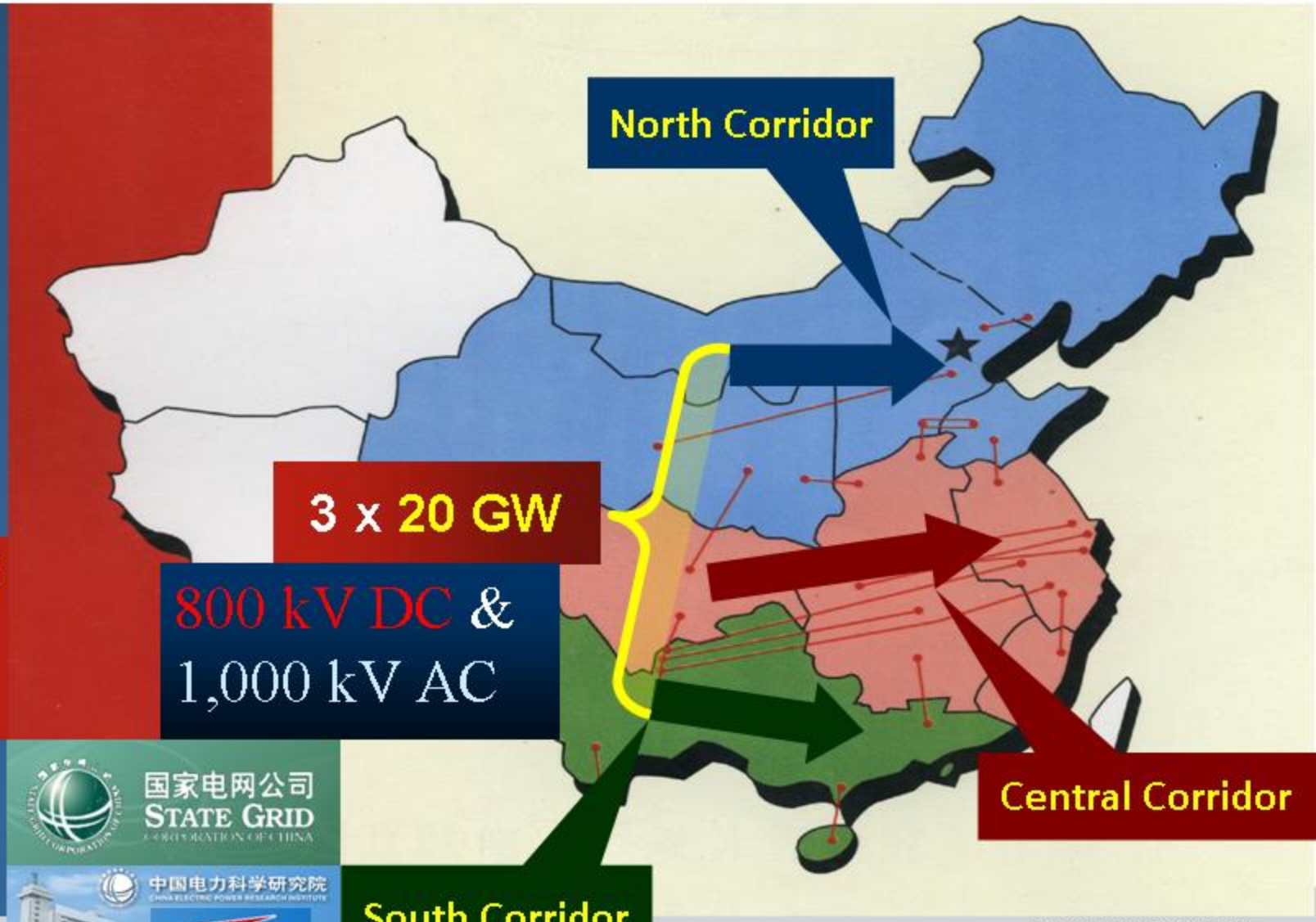
Transmission Capacity of each Corridor will be 20 GW by 2020 ...

... the installed Generation Capacity will be 900 GW



Sources:

国家电网公司 STATE GRID

中国电力科学研究院 CEPRI

Jinping ± 800 kV HVDC Transmission Project @ 6400MW of State Grid Co.

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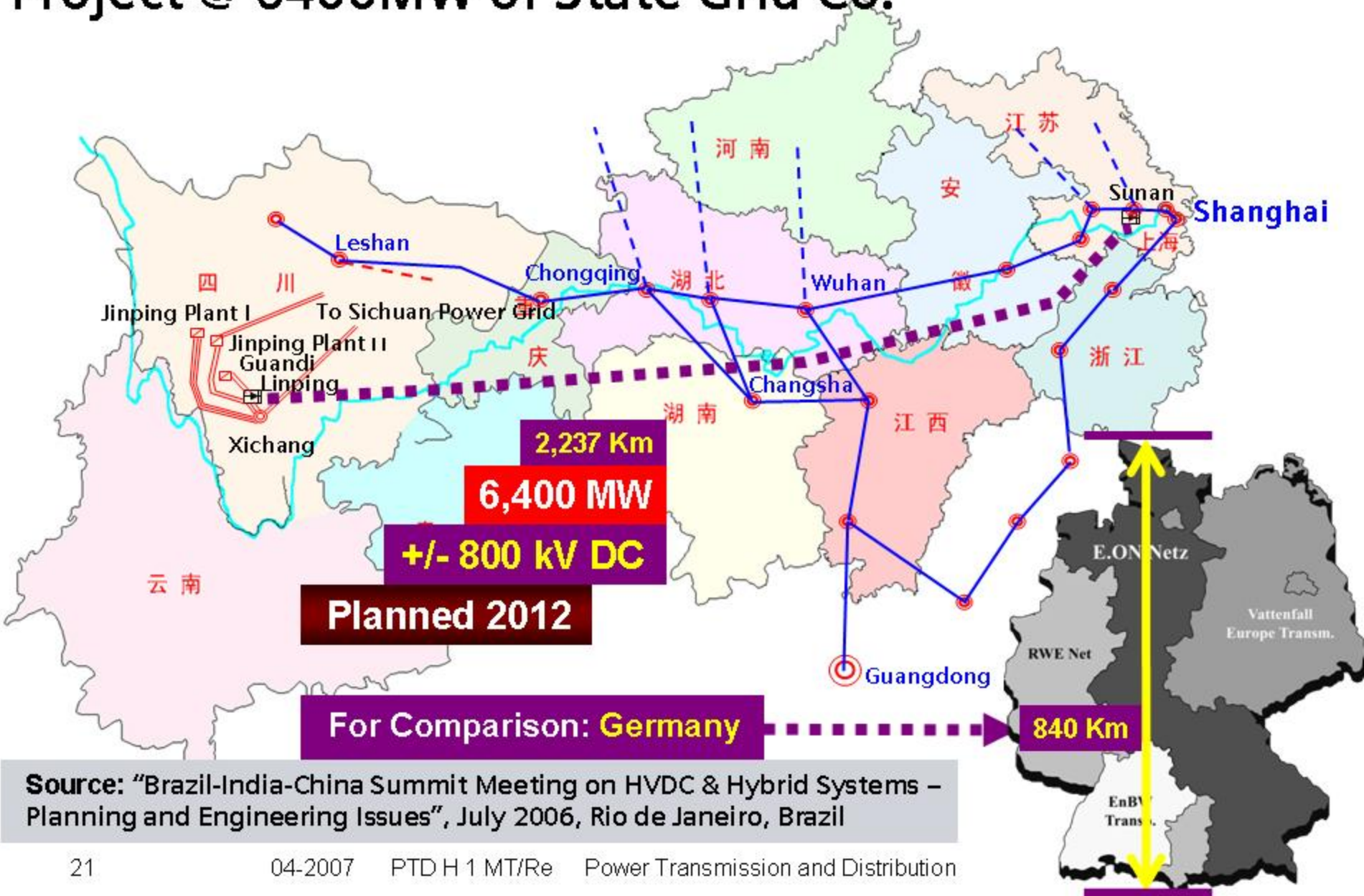

Source: "Brazil-India-China Summit Meeting on HVDC & Hybrid Systems – Planning and Engineering Issues", July 2006, Rio de Janeiro, Brazil

800kV DC Air-Core, Smoothing Reactor and Converter Transformer

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At Present 500 kV DC – but can be extended to 800 kV DC

Mostly a mechanical Issue

But not only …

UHV DC Bushing at Test Lab TU Graz

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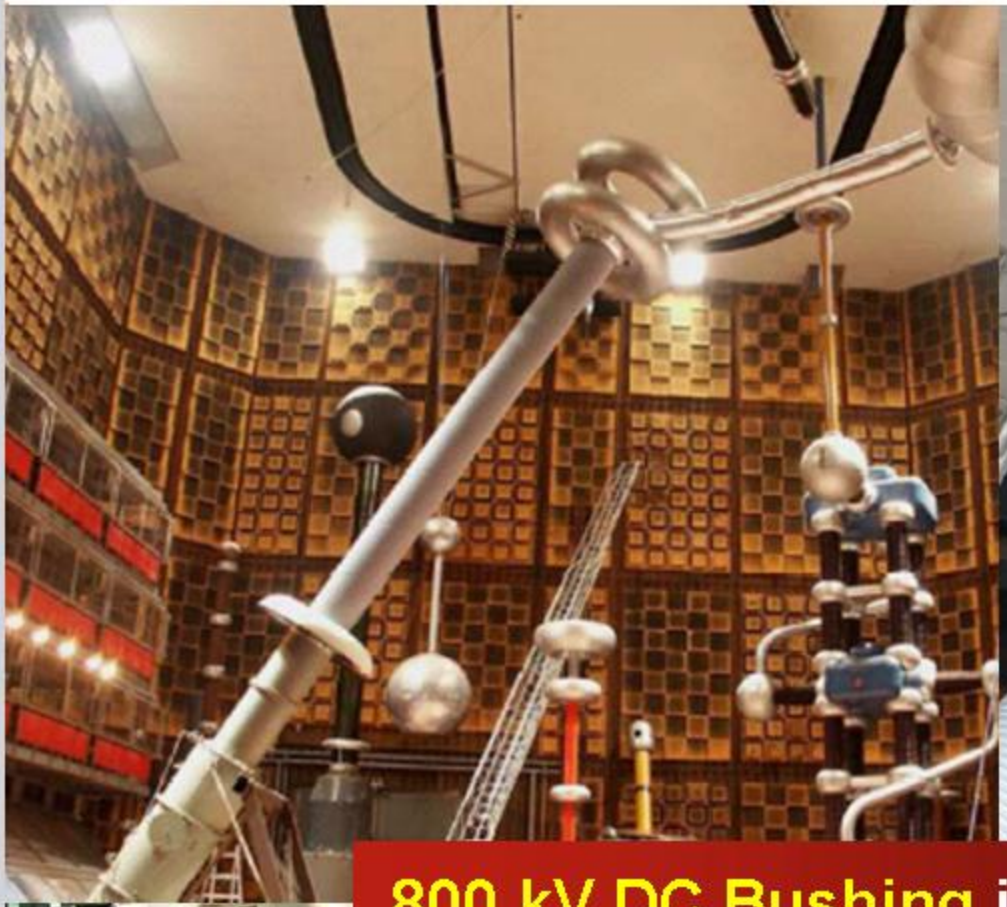

800 kV DC Bushing in Test Field

Thorough Testing is quite essential ...

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Verification of Mechanical Performance

Cantilever Bending Test *for* DC Insulators

Verification of
Clearance Distances *for* UHV DC Equipment

Testing of DC Bypass-Breaker

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400 kV DC

800 kV DC

800kV DC Valve Tower Testing

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Dielectric Testing of Valve-Support Structure

Valve Hall Configuration – for UHV DC

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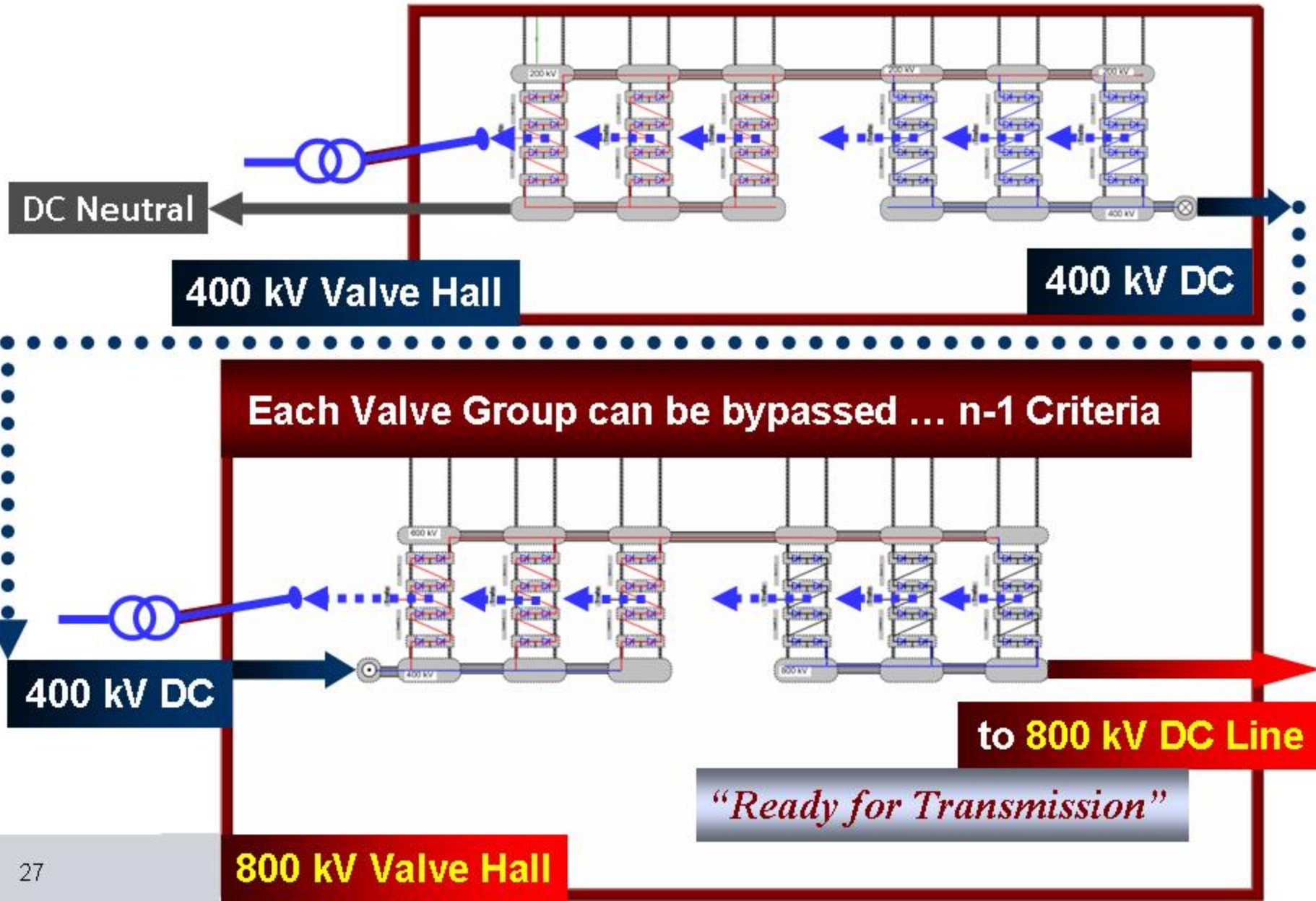

Conclusions

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Transmission ***needs*** **…**

Elimination of

Bottlenecks

and **Congestion** ***by use of***

Advanced Technologies

Siemens has been successful in the HVDC Business for more than 30 Years

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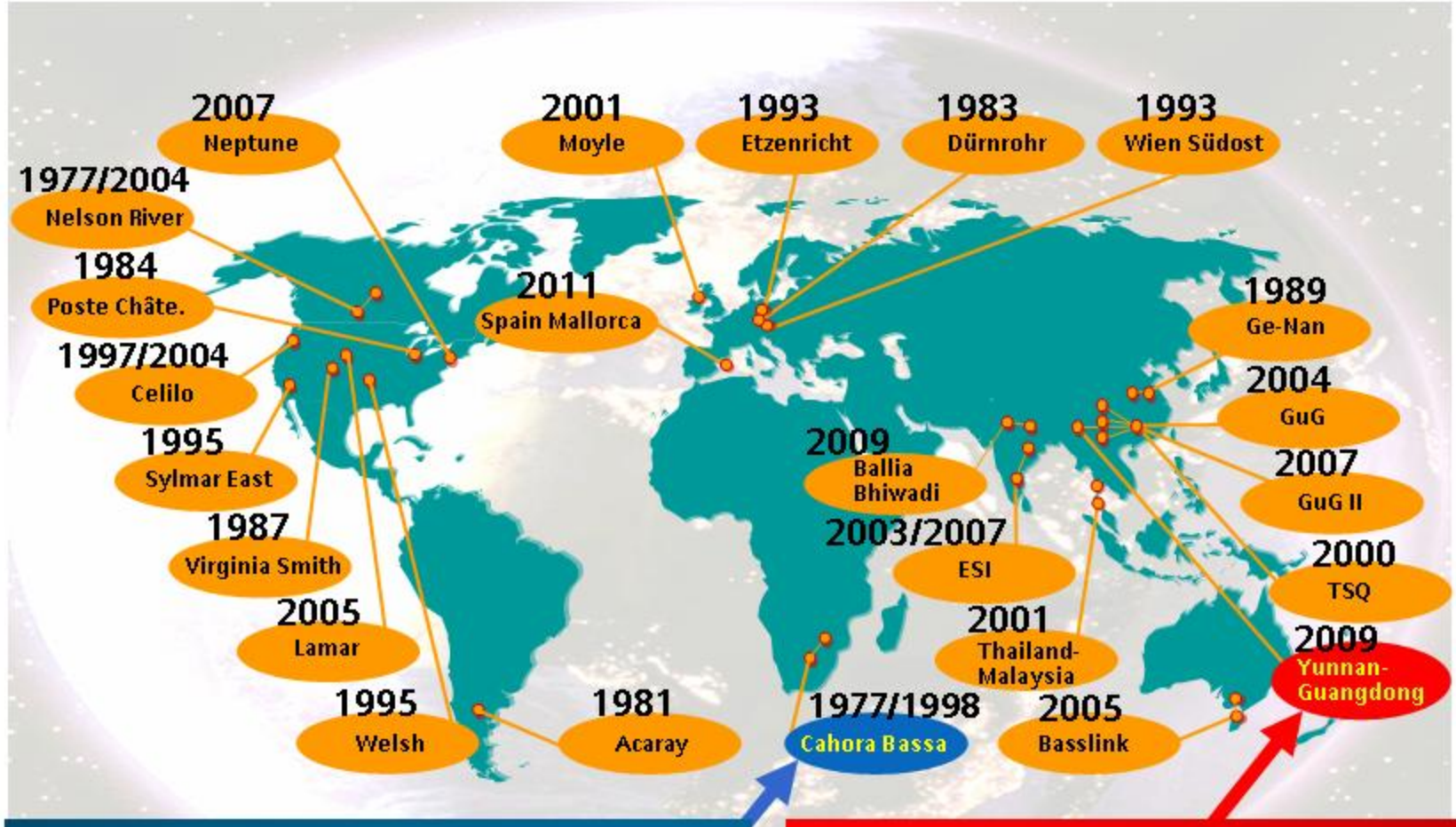

From Congestion, Bottlenecks and Blackouts towards a "Smart Grid"

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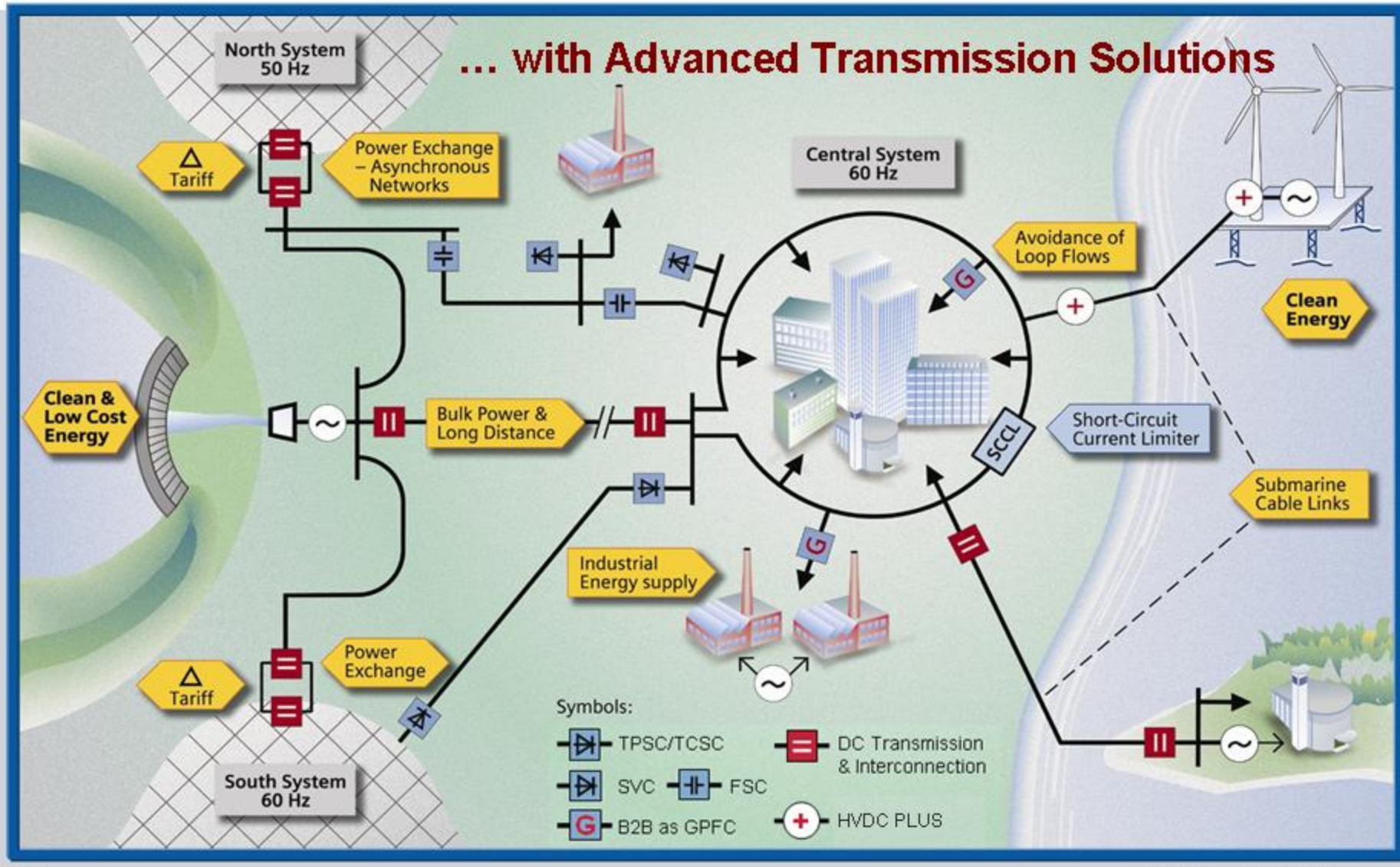

The Future ?

Global Link for Green Energy

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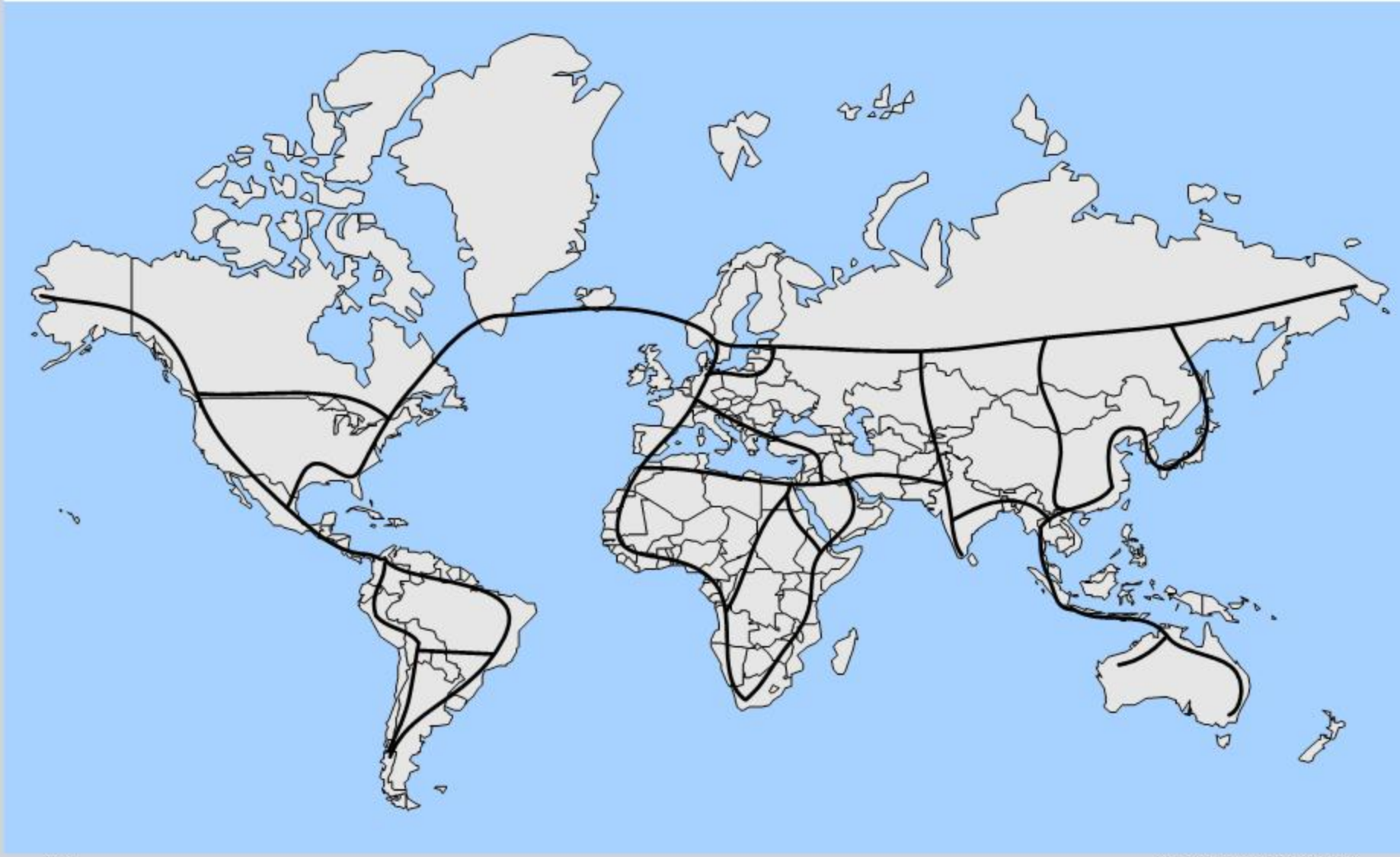

Benefits of a "Global" Solution for System Interconnection

- Solving local Problems of Energy Resources by worldwide Energy Trading
- Improving Frequency Stability in weak Systems by Support through strong Systems
- Chance to use remote Regenerative and clean Energy Production:
  - Solar Fields in Deserts
  - Off-Shore Wind Farms
  - Hydro Energy
- Independent from the Time Zones

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