Centro de Pesquisas de Energia Elétrica - CEPEL

Paradigms in Power System Planning & Operation Contemplating the HVDC Technological Evolution

SEMINARIO

Planificación Energética y de Expansión de la Transmisión

CIGRE CHILE

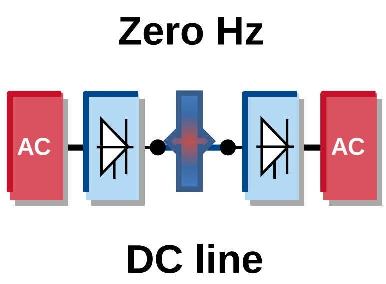
Marcio Szechtman
Director General

Santiago, Abril 16, 2018

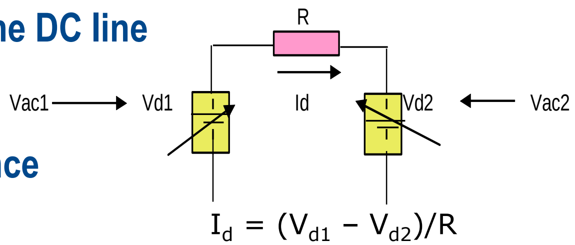
HVDC – from traditional applications towards new market roles

HVDC – Main Inherent Characteristics

- ✓ Frequency Decoupler



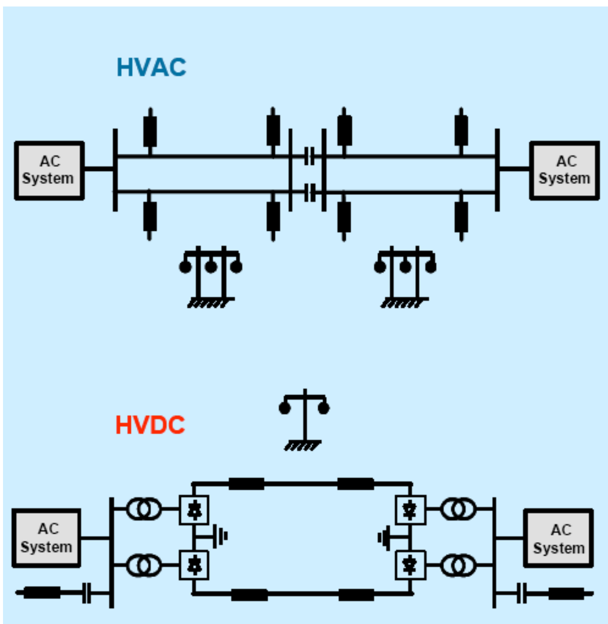
- ✓ No reactive power flow in the DC line
  - ✓ Basically a resistance



- ✓ And, moreover, the active power flow corresponds exactly to the Operator's dispatch

HVDC Traditional applications

- 1) Long Distance Transmission:



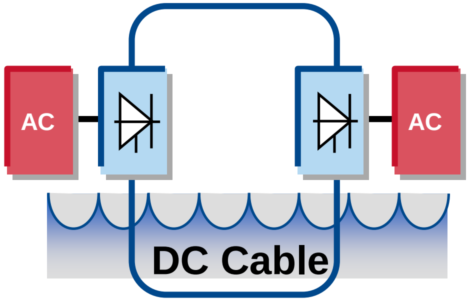
- ✓ Synchronous Systems
- ✓ Three phase condutctors
- ✓ Intermmediate substations for Voltage and Switching Overvoltage control at each 300 to 400 km

- ✓ Asynchronous Systems
- ✓ 2 Conductors (+ and - poles)
- ✓ DirectTransmission

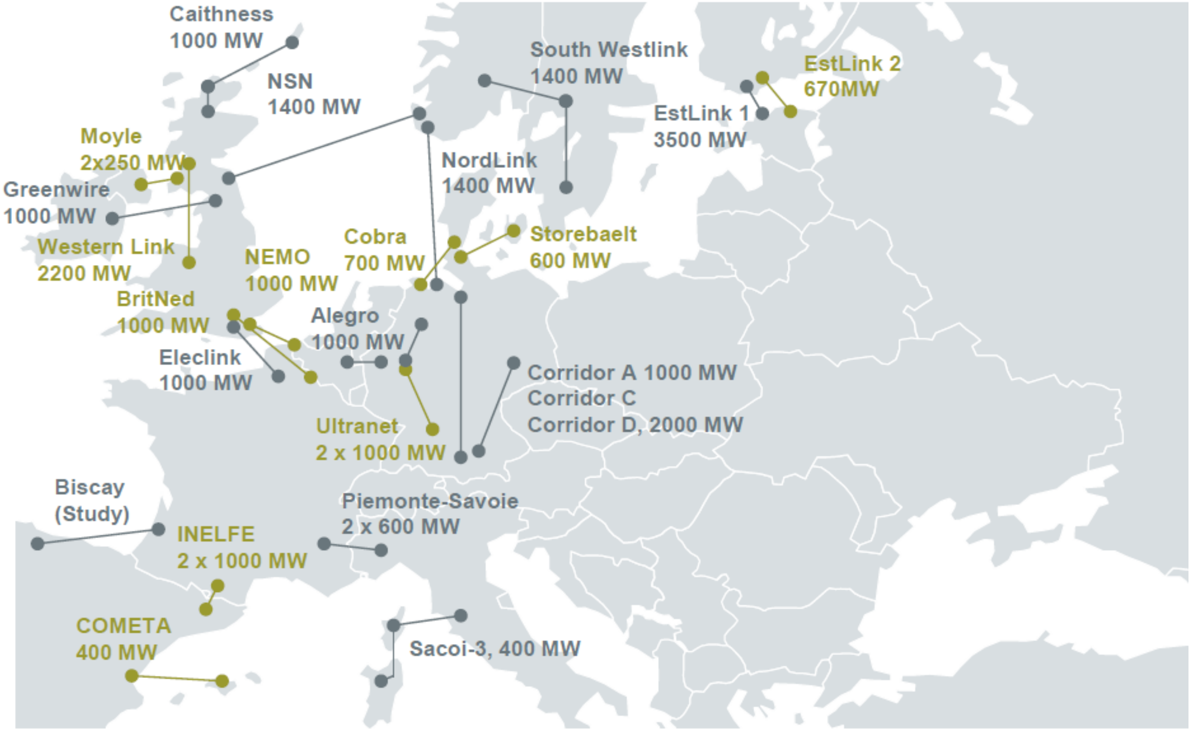
HVDC Traditional applications

- 2) Submarine or Underground Transmission:

As there is no charging effect, applications beyond 100 km are feasible with DC

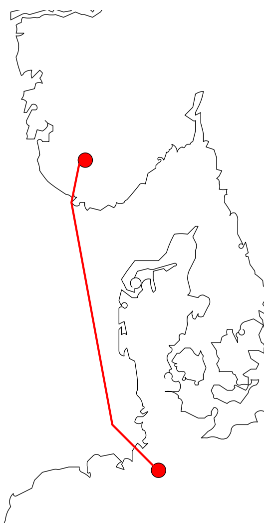


As we can see in many parts of Europe

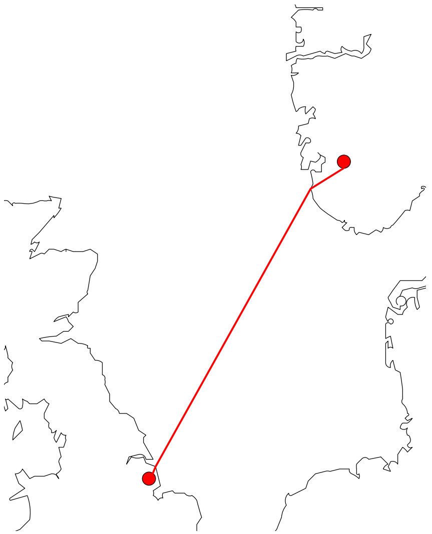


Recent Examples of North Sea Interconnetions

NordLink – Norway - Netherlands
Statnett, Tennet, KfW
1400 MW +/- 525 kV
VSC Converters
Bipole
Tonstad in Norway – Wilster in Germany
571 km cable + 53 km OH-line
Commissioning 2019

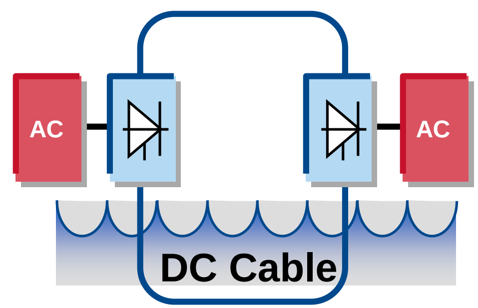


North Seal Link
Statnett and National Grid
1400 MW +/- 515 kV
VSC Converters
Bipole
Suldal in Norway – Newcastle area in England
722 km
Commissioning 2021



HVDC Traditional applications

- ✓ 3) Off-shore Wind Farms Transmission

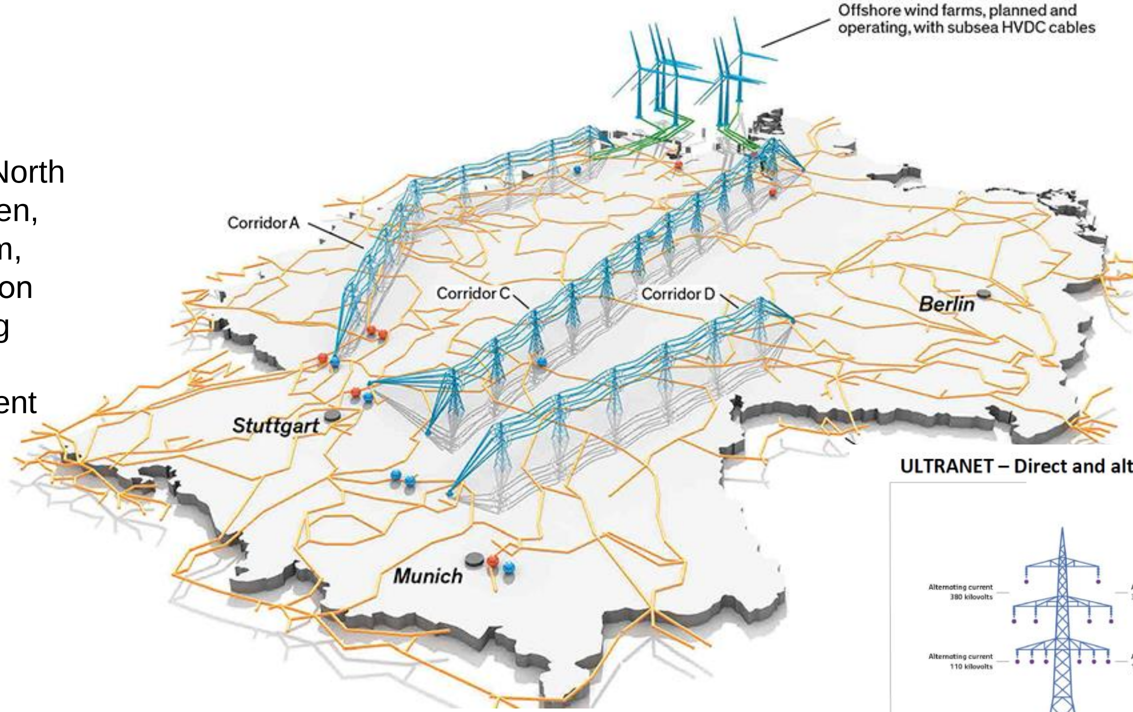


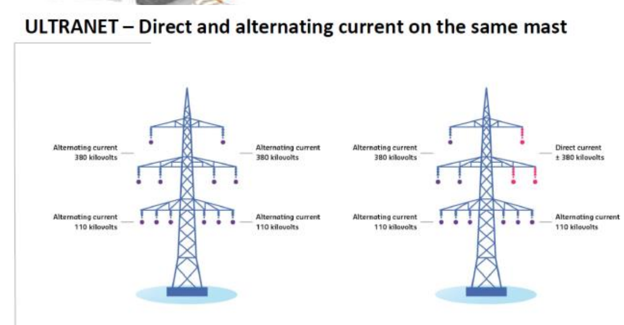
HVDC Traditional applications

Eletrobras
Cepel

Off-shore Wind Farms: they need to reach load centers (Example fo Germany)

Corridor A, to be strung from the North Sea port of Emden, 1000 MW 660 km, part of a €10 billion project still being debated by the German parliament



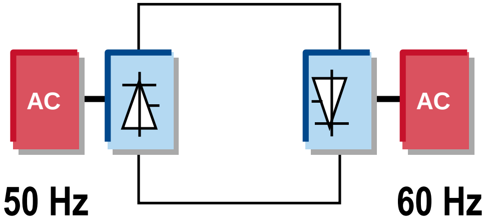


amprion TRANSNET BW

HVDC Traditional applications

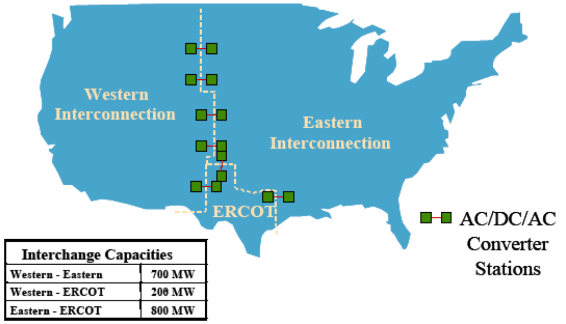
- 4) Interconnection of systems at different frequencies:

Many examples in South America: Garabi (AR/BR), Rivera, Mello (UR/BR)



- 5) Asynchronous Operation:

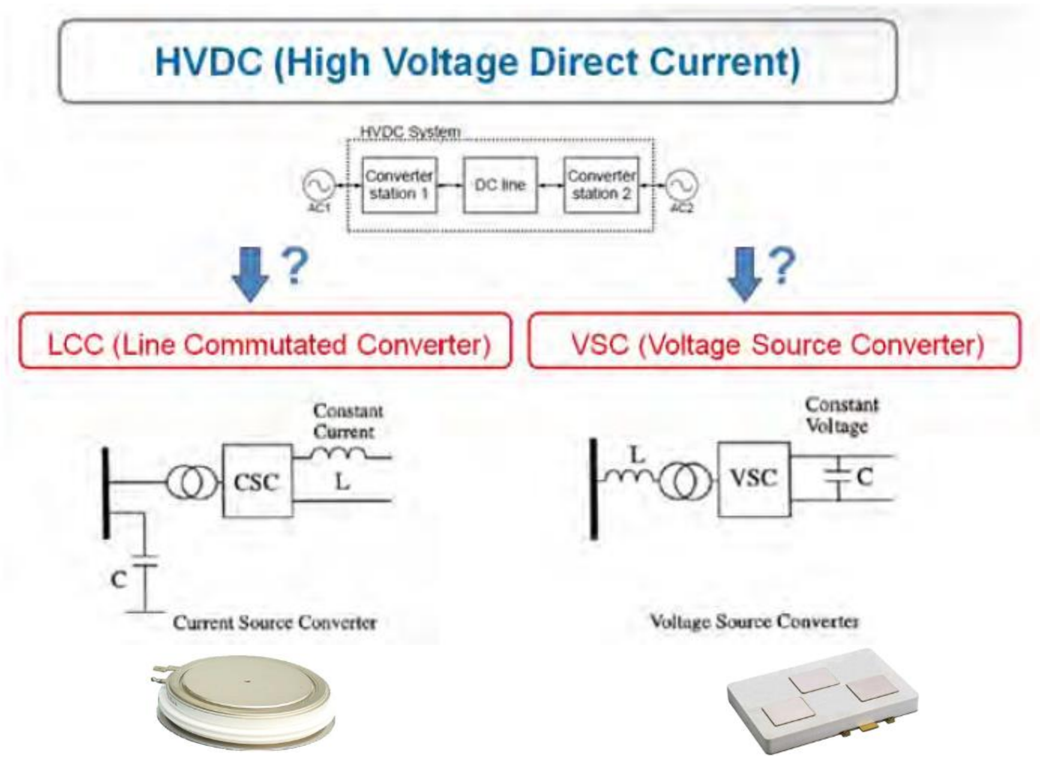
Example of the
East/West/Texas USA islanding
BtB



Interchange Capacities	
Western - Eastern	700 MW
Western - ERCOT	200 MW
Eastern - ERCOT	800 MW

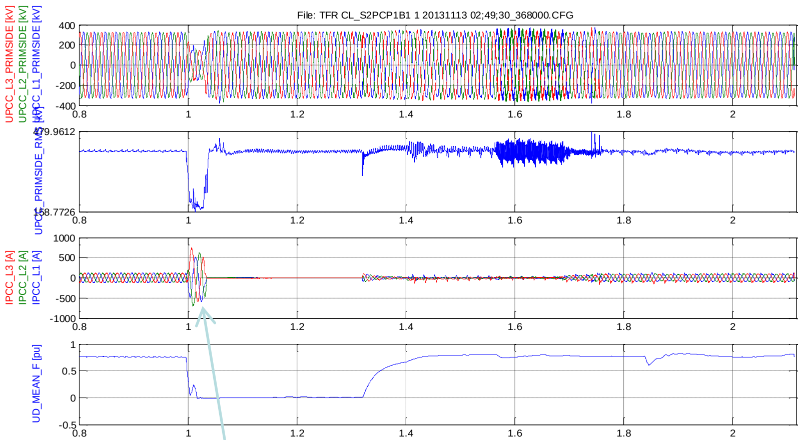
HVDC Technological Evolution and Trends

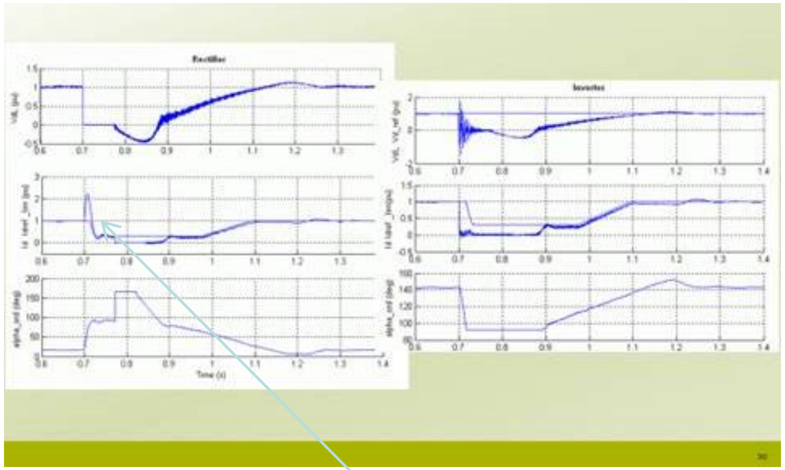
LCC or VSC?



HVDC (High Voltage Direct Current)
HVDC System
Converter station 1
DC line
Converter station 2
AC1
AC2
?
?
LCC (Line Commutated Converter)
VSC (Voltage Source Converter)
Constant Current
CSC
L
C
Current Source Converter
Constant Voltage
L
VSC
C
Voltage Source Converter

VSC and LCC Responses to Line fault





Fault current cleared by AC breaker (3 cycles); full recovery time, from 700 to 1500 ms; with DC breakers or full bridge, time will be less

Fault current cleared by Thyristor control in 10 ms; typical straight forward recovery time in the range of 400 ms, including arc deionization

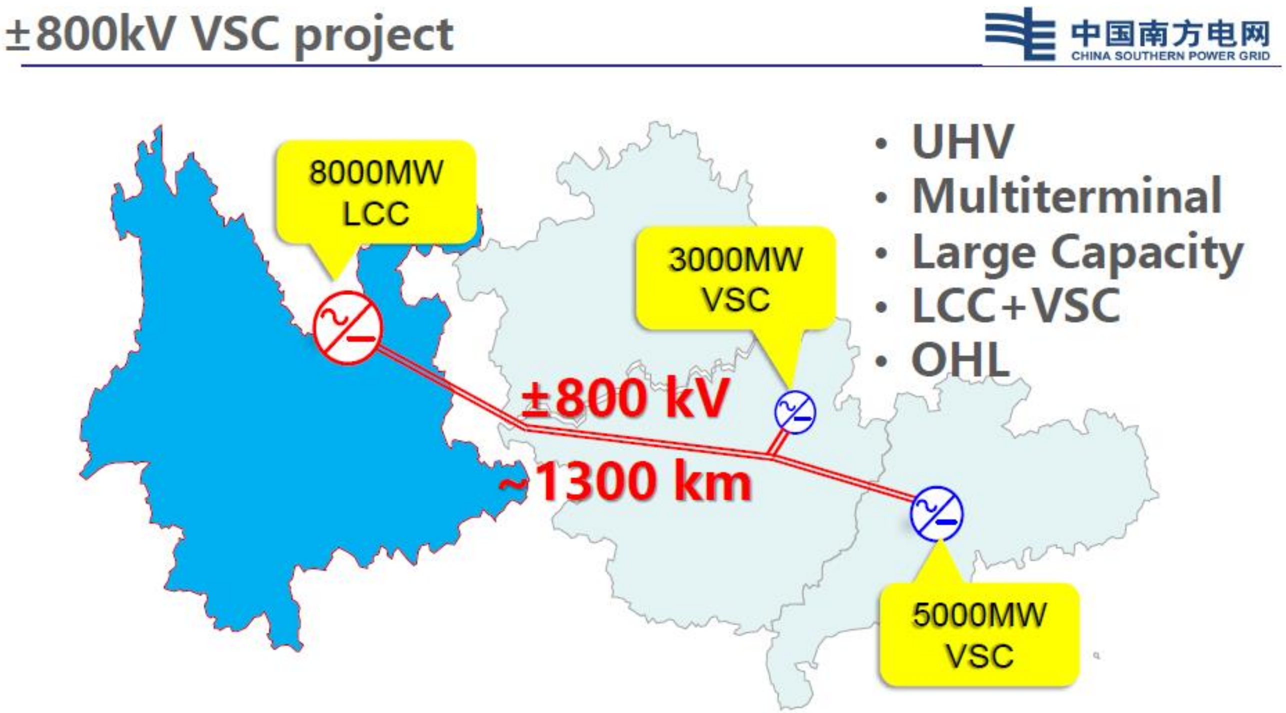
HVDC response due to a mid-line pole DC fault: left VSC System; right typical LCC Scheme

HVDC – The Chinese breakthrough

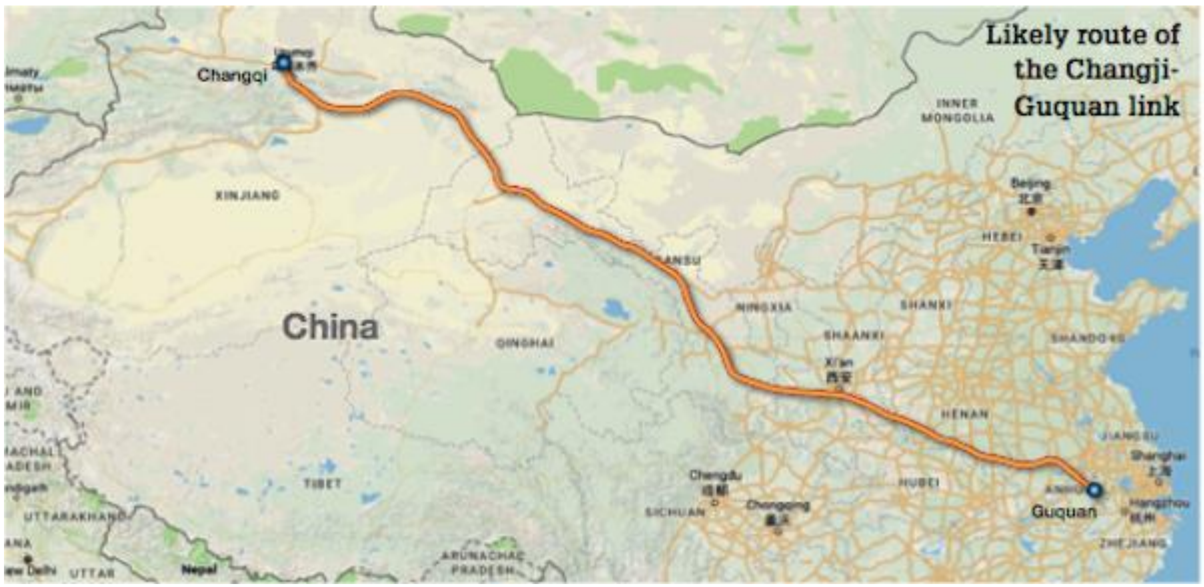
Name	Volt (kV)	Power (MW)	Year
Humeng - Shandong	800	6400	2015
Inner Mongolia - Linyi	800	6400	2017
Irkutsk - Beijing	800	6400	2015
Jinsha River II - East China	800	6400	2016
Xilin Hot - Taizhou	800	6400	2017
Goupitan - Guangdong		3000	2016
Jiuquan- Xiangtan	800	6400	2016
Yinchuan - Zhuji	800	6400	2017
Jinsha River II - Fujian	800	6400	2018
Northwest Yunnan - Guangdong	800	6400	2017
Humeng - Liaoning	800	6400	2018
Xinjiang - Anhui	1100	10000	2017

Only these projects add to new 80000 MW!

HVDC – New Frontiers to be accomplished in China



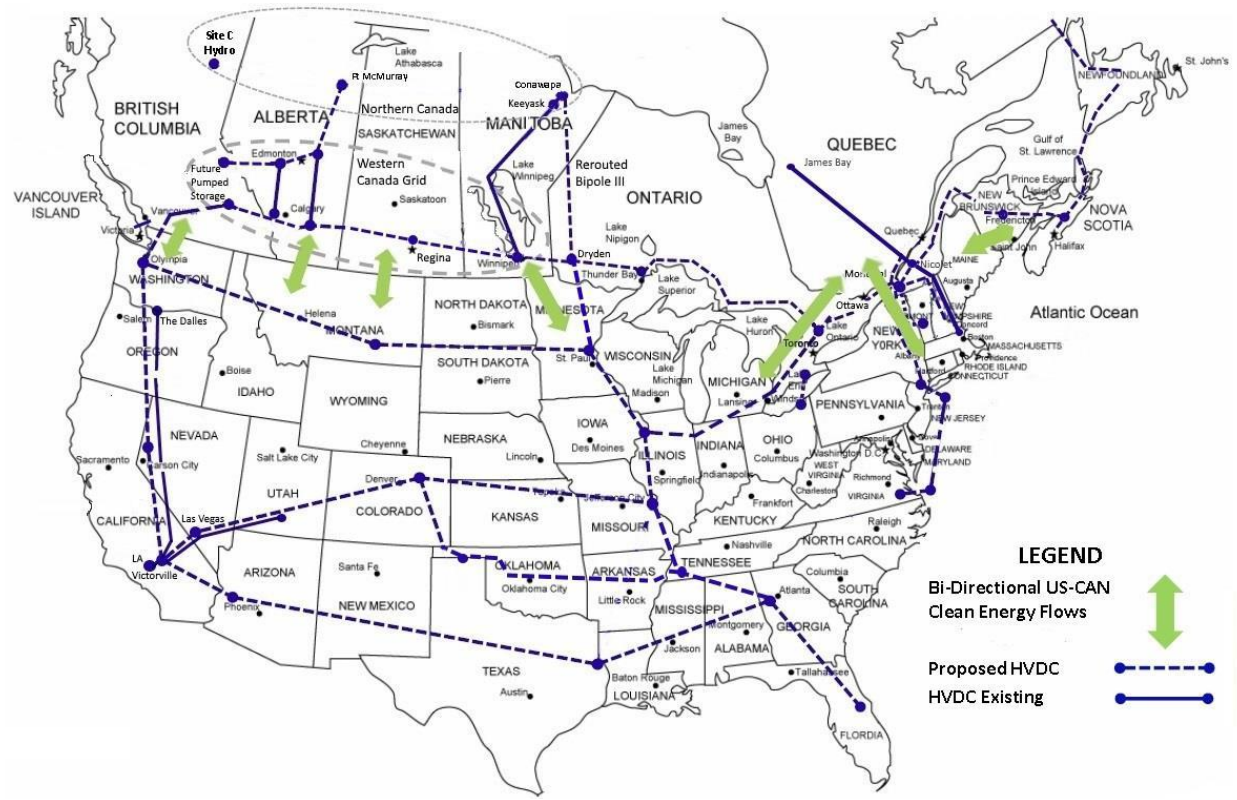
HVDC – The Chinese breakthrough
The ±1100 kV, 12000 MW, 3300 km SGCC Project



587 MVA power transformers supplied by SIEMENS, ABB and Chinese Manufacturers

New trends in HVDC – The Overlaying
The Chinese idea of the Asian Interconnection

New trends in HVDC – North America Transmission Overlaying



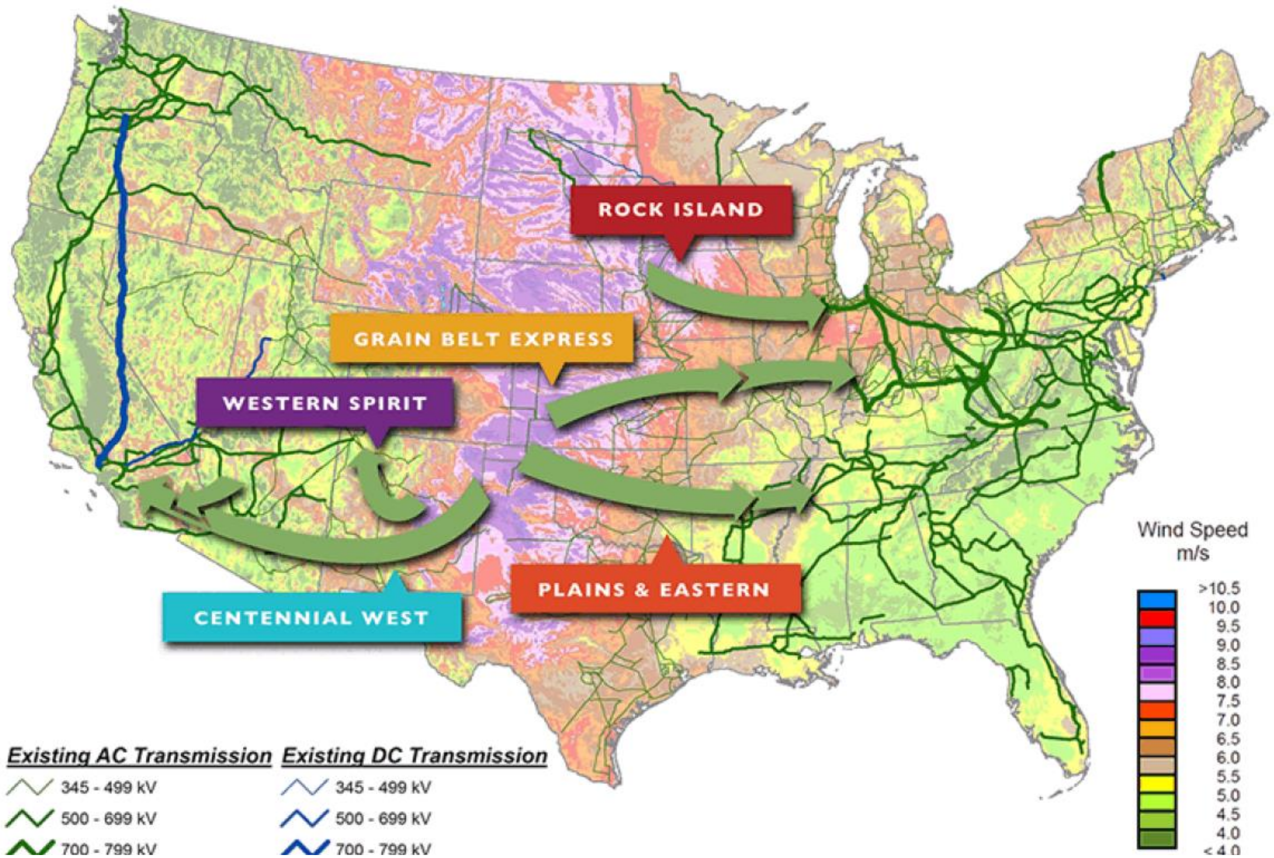
Renewable Energy Evacuation in the USA

Eletrobras Cepel

Using Classic LCC HVDC to Transmit Renewable Energy from Weak AC Systems

D. KELL, R. OSTASH, M. MOHADDES
TransGrid Solutions

W. GALLI
Clean Line Energy



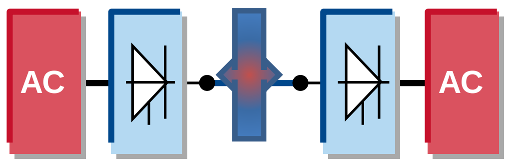
New Paradigms in Power System Planning considering HVDC

New Paradigms?

Zero Hz: no trasnfer of short circuit current or oscillatory modes

Zero “km”: there is no electrical distance: generation gets closer to loads

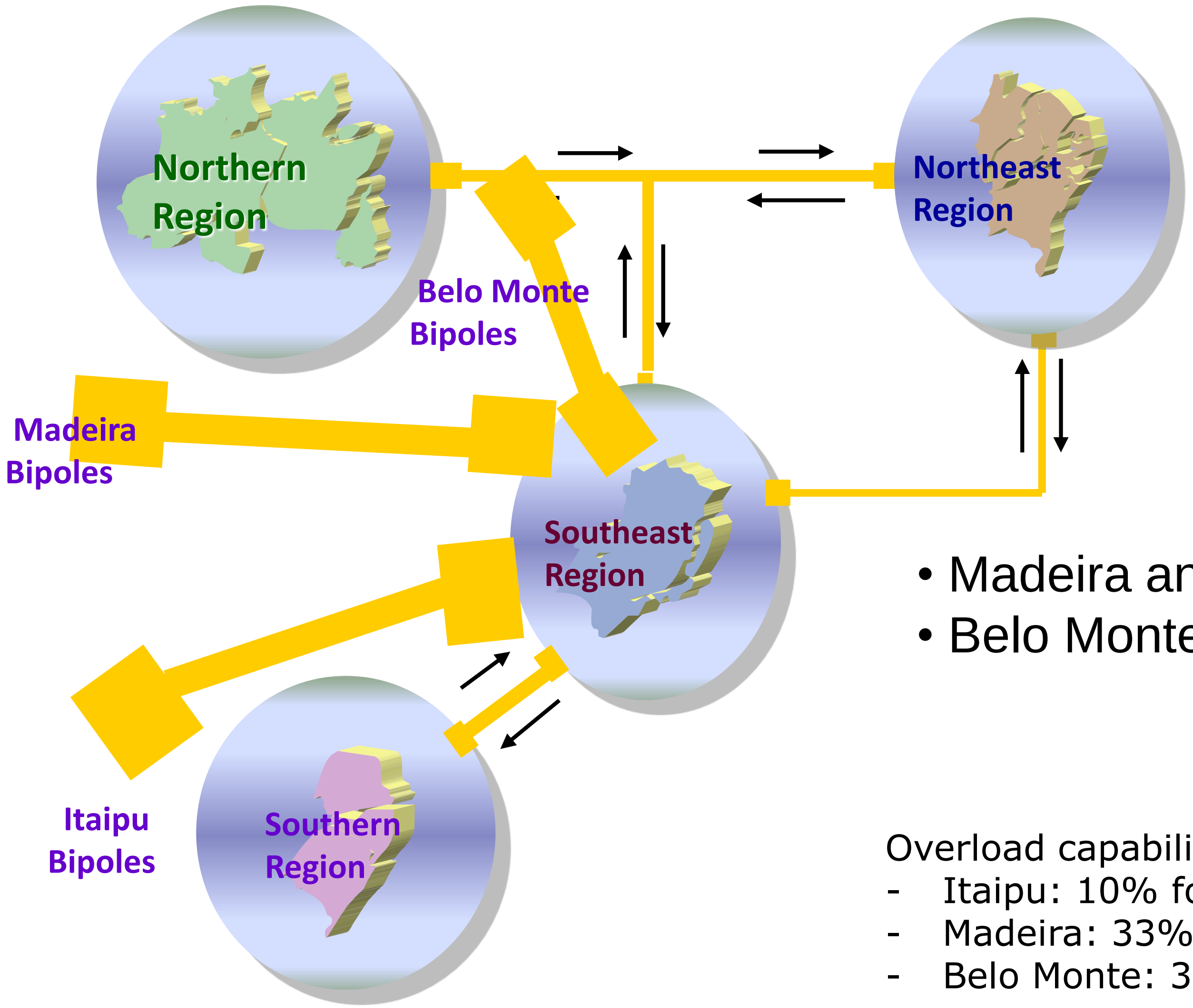
Zero Hz



Zero km

The Brazilian Transmission Grid
New Paradigms

Eletrobras Cepel

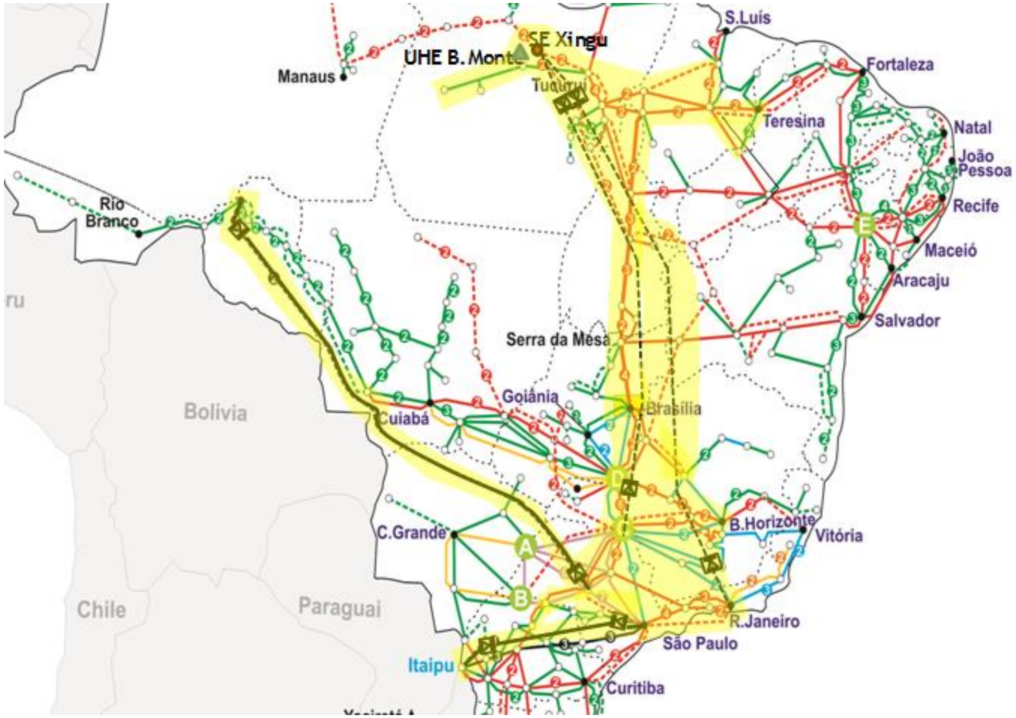


- Madeira and Itaipu: assinchronous
- Belo Monte: system embedded and bi-directional

Overload capability (30 min) specified:

- Itaipu: 10% for a Pole Contingency
- Madeira: 33% for any DC Contingency
- Belo Monte: 33% for any AC or DC event

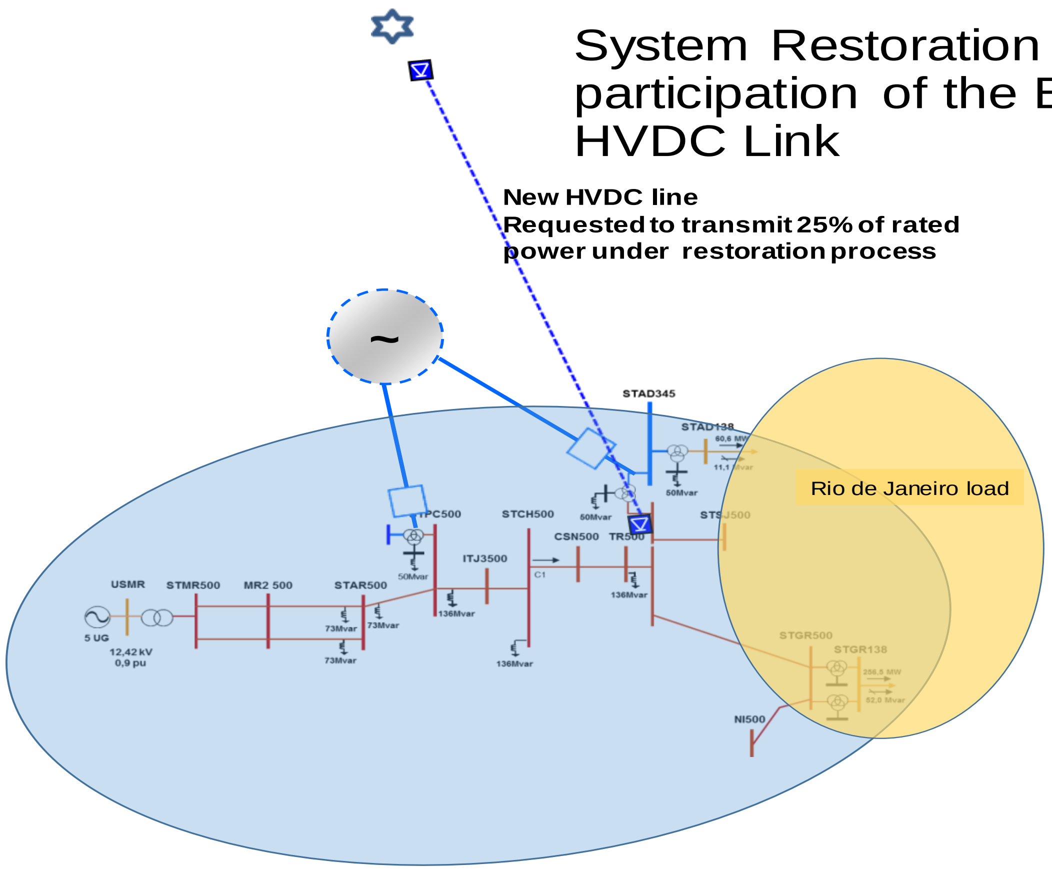
HVDC is now embedded



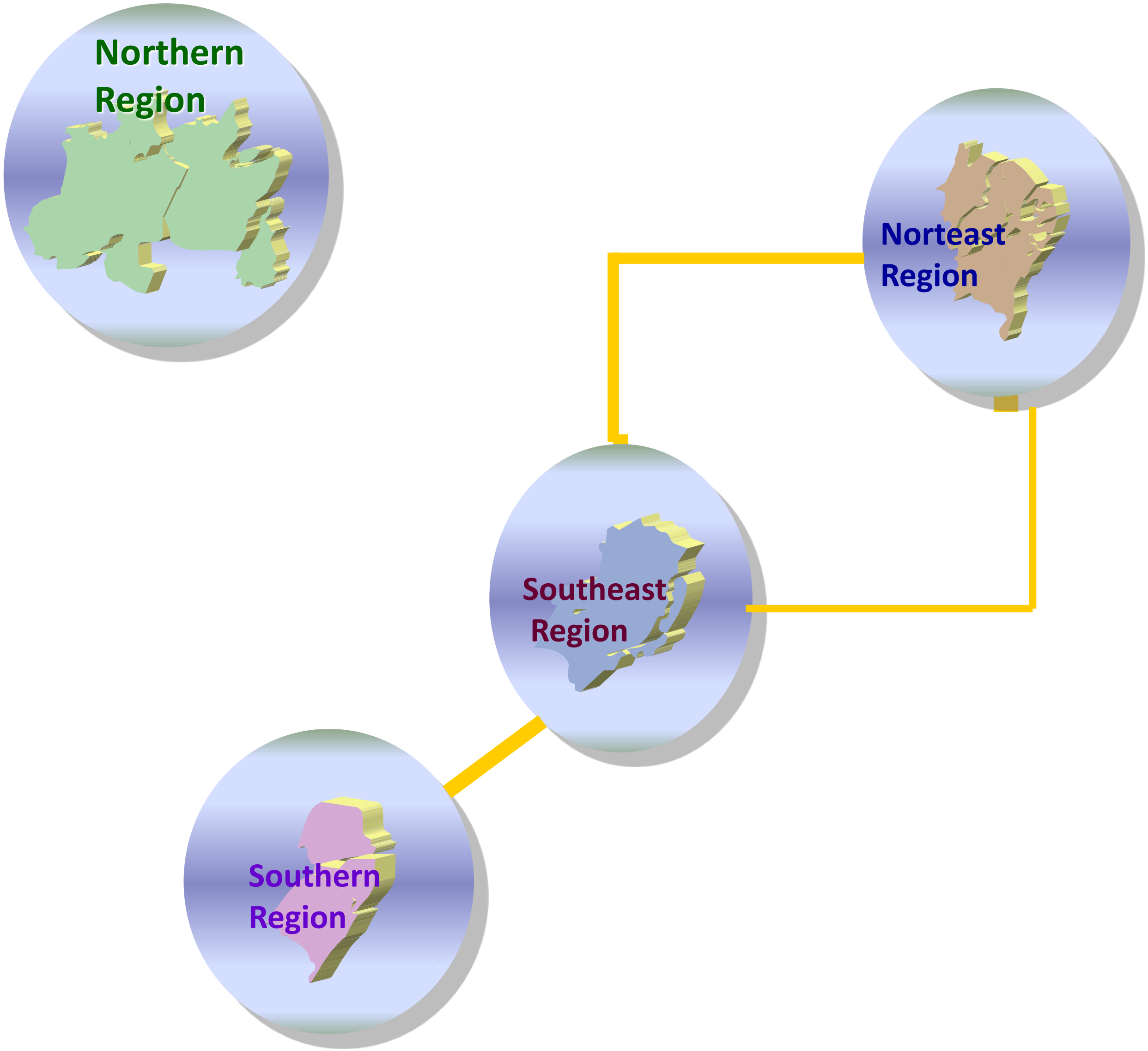
In addition:
The Belo Monte HVDC run in close proximity of large 500 kV AC trunks

HVDC Role in System Restoration

System Restoration with the participation of the Belo Monte BP2 HVDC Link



The Effect upon diferente markets (or sub-markets in Brasil)



Hydrological Complementary among Basins – Storage on a System Basis

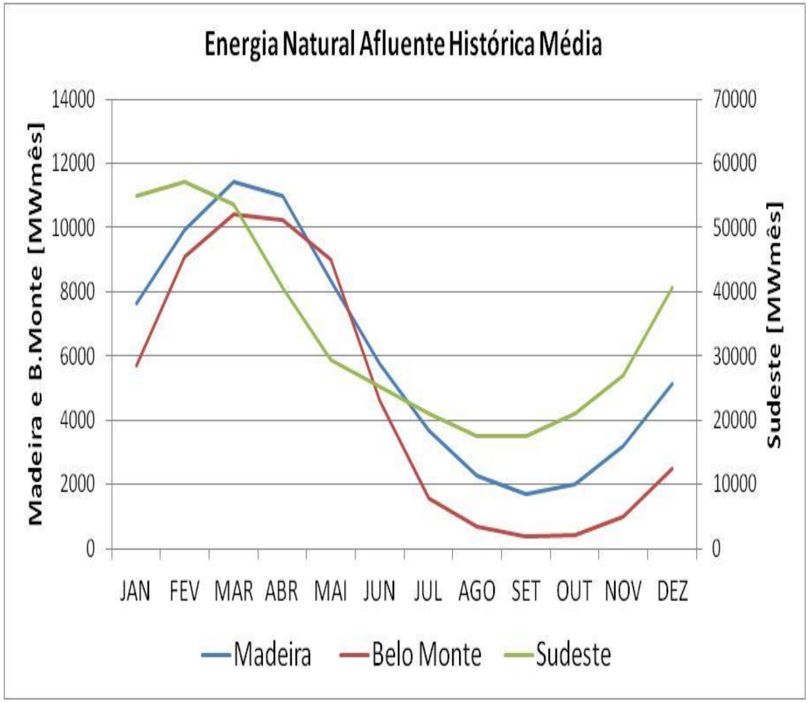
- Two months displacement among basins
- Allow water reserves
- Gains on operational costs and reliability

•In this way, storage of water (Energy) may be executed, on a systemic basis

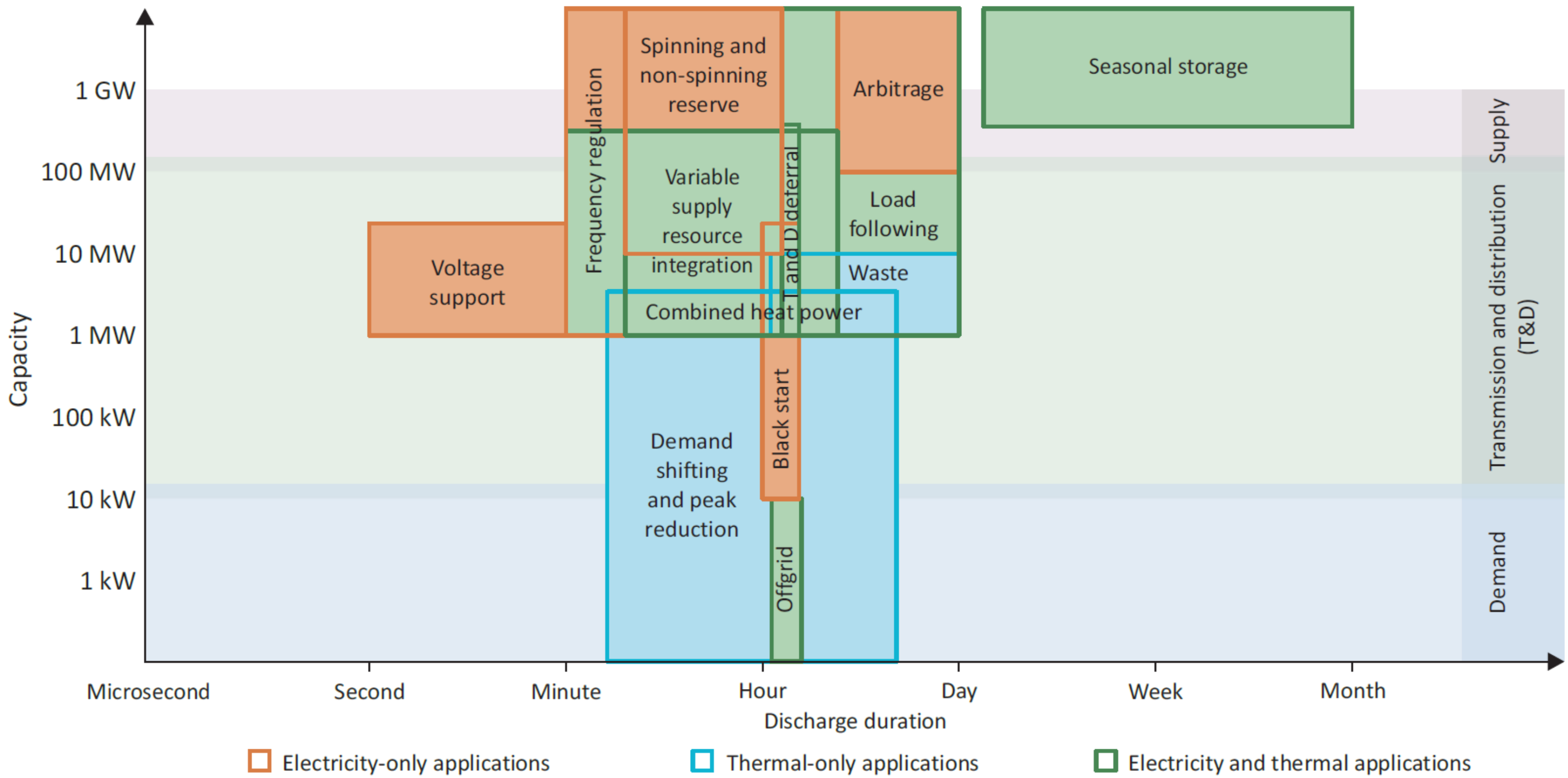
On a local basis:

- Key technology to provide more flexibility

•To compensate sudden variations of power generation and loads



About Storage: System and Local

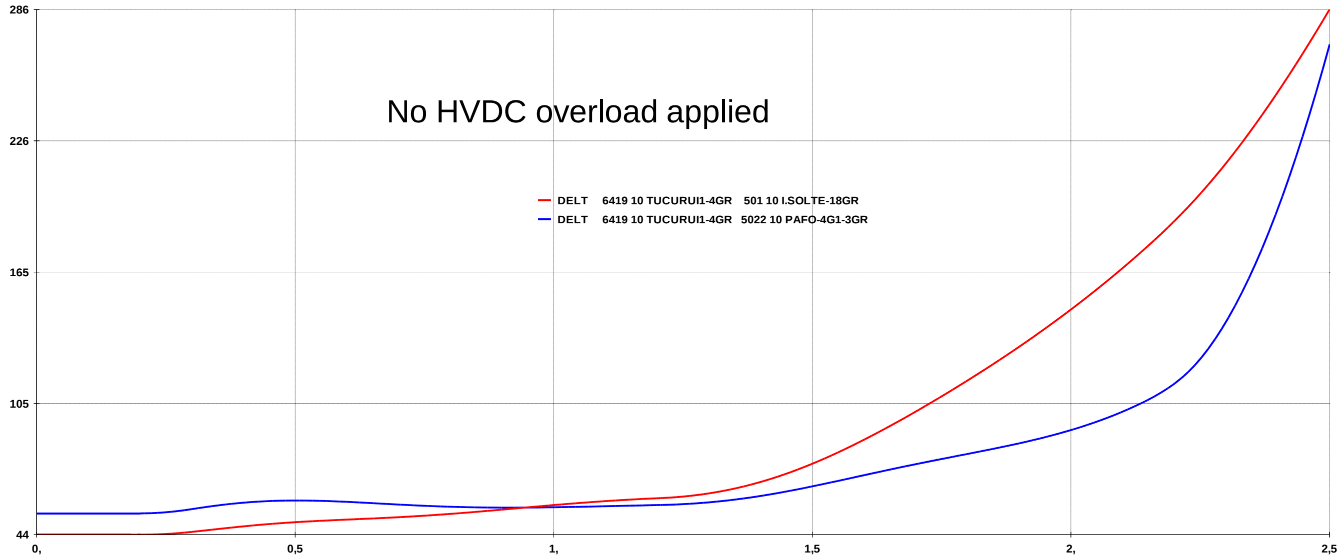


Source: IEA Technology Roadmap Energy Storage (2014)

Expoiting the DC Power Overload Capability of HVDC Links

Eletrobras Cepel

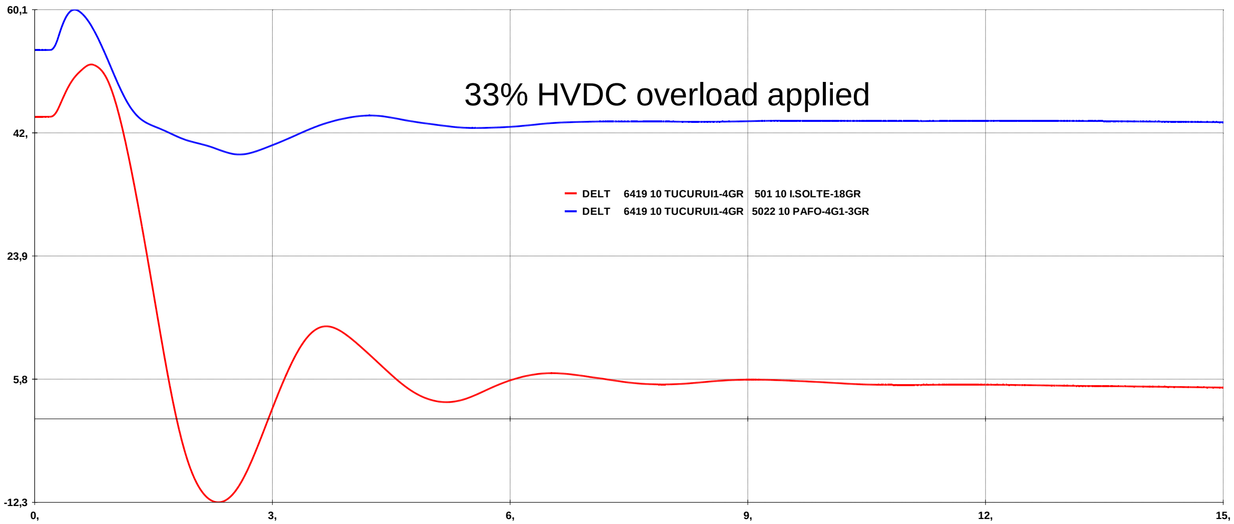
Generators angle separation for a double circuit 500 kV AC fault:
red: North to Southeast; blue: North to Northeast



Eletrobras Cepel

Expoiting the DC Power Overload Capability of Belo Monte HVDC Links (33% for 30 minutes)

Generators angle separation for a double circuit 500 kV AC fault:
red: North to Southeast; blue: North to Northeast



Presently, no dynamic overload is available with VSC Systems

THANK YOU!