HVDC Technology key issues for future grids
Opening Speech

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For power system expertise

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- The Electrical Energy Disruptive Evolution
- Concerns about the Environment
- Options for Future Grid
- HVDC Role
- The Technology for HVDC Grids
- HVDC as a mean to make optimal use of Renewable Energy Resources
- Conclusions

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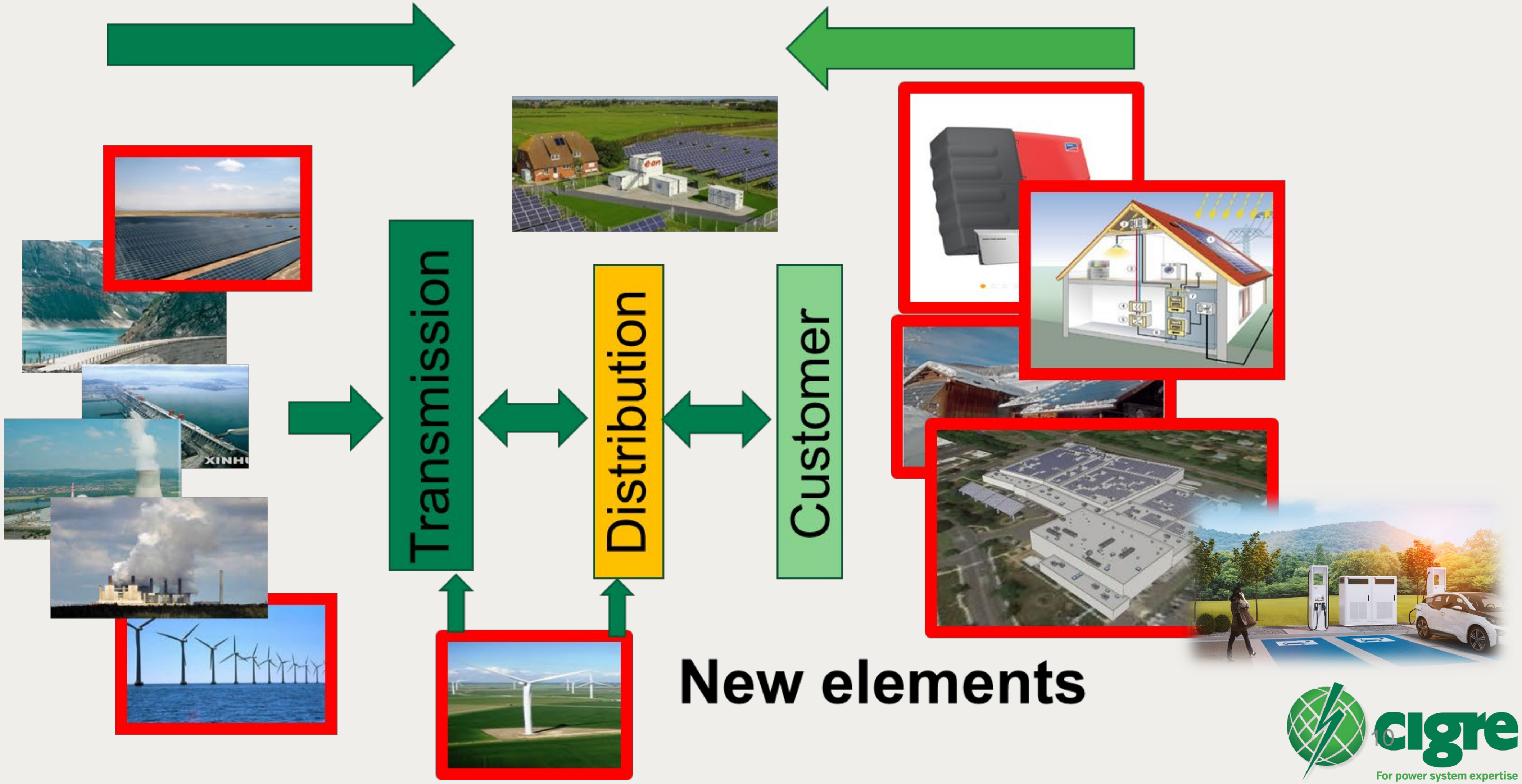
THE ELECTRICITY SECTOR DISRUPTIVE CHANGES



FUTURE GRID - TEN AREAS OF FOCUS

1. ACTIVE DISTRIBUTION NETWORKS
2. MASSIVE EXCHANGE OF INFORMATION
3. INTEGRATION OF HV AND MV DC/POWER ELECTRONICS
4. SIGNIFICANT INSTALLATION OF STORAGE
5. NEW SYSTEMS OPERATIONS /CONTROLS CONSIDERING ENVIRONMENTAL ASPECTS
6. NEW CONCEPTS FOR PROTECTION
7. NEW CONCEPTS IN PLANNING FOR SUSTAINABLE SYSTEMS
8. NEW TOOLS FOR TECHNICAL PERFORMANCE
9. INCREASED USE OF EXISTING INFRASTRUCTURE AND NEW T&D DEVELOPMENTS
10. STAKEHOLDER AWARENESS; MARKET &REGULATORY INTEGRATED CHAIN

KEY ISSUES IN THE ELECTRICITY SECTOR

1. INCREASE USE OF ELECTRICITY IS A NO-RETURN TREND
2. DISTRIBUTION LEVEL SYSTEMS WITH MUCH DYNAMISM
3. IT IS NO LONGER POSSIBLE TO DEAL WITH G&T SEPARETLY FROM D
4. ELECTRICTY SECTOR IS RESPONSIBLE FOR 25% OF CO2 EMISSIONS
5. SDG 13 OF THE PARIS AGREEMENT MORE DIFFICULT TO ACHIEVE
6. HIGH PENETRATRION OF INTERMITTENT RES RAISES THE QUESTION OF SECURITY OF SUPPLY AND BACKUP STRUCTURE
7. FOR THE FUTURE, CAN WE AVOID OR HAVE ANOTHER OPTION BESIDES GOING FUTHER TO AN INTERCONNECTED WORLD

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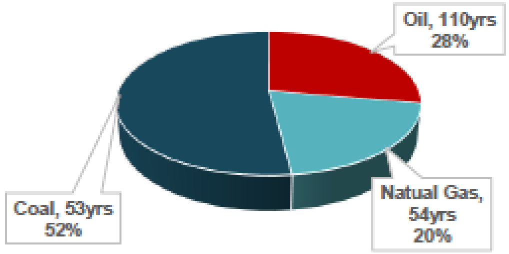
SOME UNDOUBTABLE FACTS

The large-scale utilization of fossil energy has resulted in a series of prominent problems

Resource shortages

- Occasional resource shortages
- Fluctuating energy market

Proven reserve of fossil fuels

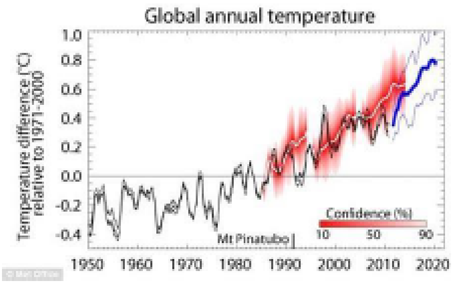


Environmental pollution

- Disasters like photochemical smog
- Acid rain and ammonia pollution

Climate change

- Global warming



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ADVANTAGES OF INTERCONNECTIONS

- SUPPORTS A BALANCED COORDINATION OF POWER SUPPLY FOR ALL INTERCONNECTED COUNTRIES
- ENABLES AN OPTIMAL USE OF RENEWABLE AND CLEAN ENERGY RESOURCES
- TAKE ADVANTAGE OF DIVERSITY ON SEASONAL AND TIME-ZONE BOTH FOR GENERATION AND DEMAND

HOWEVER,

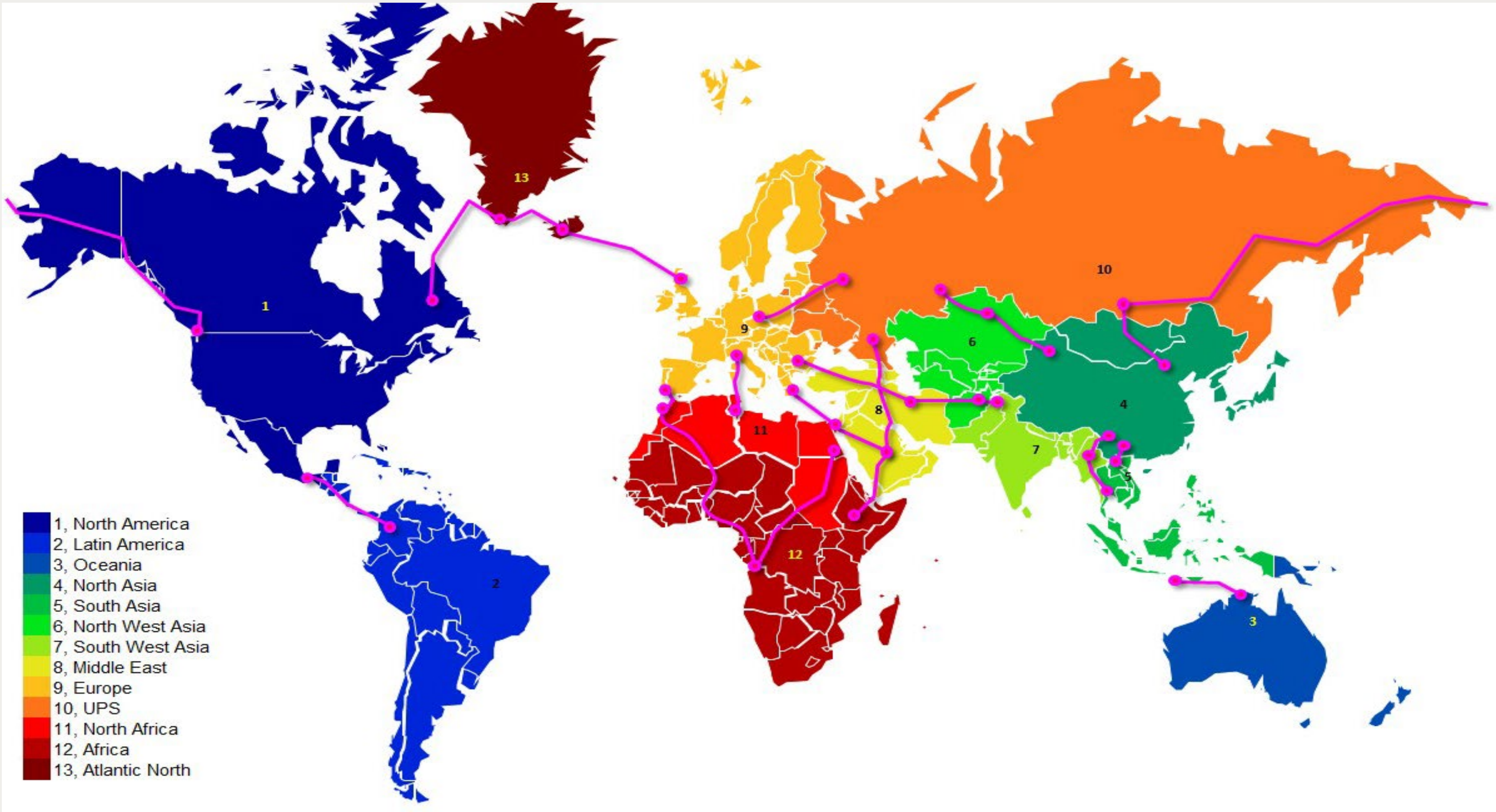
- RELY ON DIALOGUE AND COOPERATION AMONG COUNTRIES AND REGIONS
- MANY SUCCESFUL EXPERIENCES ARE ALREADY IN PLACE (EUROPE, CENTRAL AMERICA etc.)
- THOSE EXPERIENCES NEED TO BE EXPANDED AND FURTHER PROMOTED

ABOUT INTERCONNECTIONS

- FUNDAMENTAL QUESTIONS:
  - DO WE HAVE THE NECESSARY TECHNOLOGY TO PLAN AND WORK ON VERY LARGE TRANSMISSION INTERCONNECTIONS?
  - ARE WE CAPABLE OF DESIGNING SYSTEMS WITH 4000 KM TO 6000 KM OF LENGHT? (*)
  - AND TRANSPORTING ABOVE 10,000 MW?

* HVDC OHL show approximately 6Ω/each 1000 km

Summary of CIGRE WG C1.35 on Global Electricity Network Feasibility



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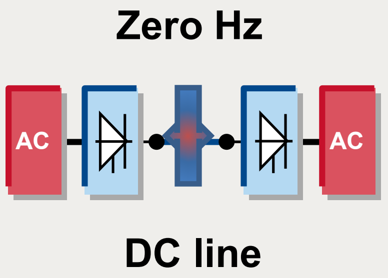
HVDC – Main Inherent Characteristics

✓ Frequency Decoupler

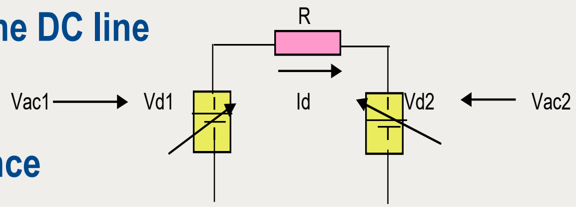


Zero Hz: no oscillation modes transfers

Zero “km”: approximation effect of sending and receiving end terminals

✓ No reactive power flow in the DC line

✓ Basically a resistance

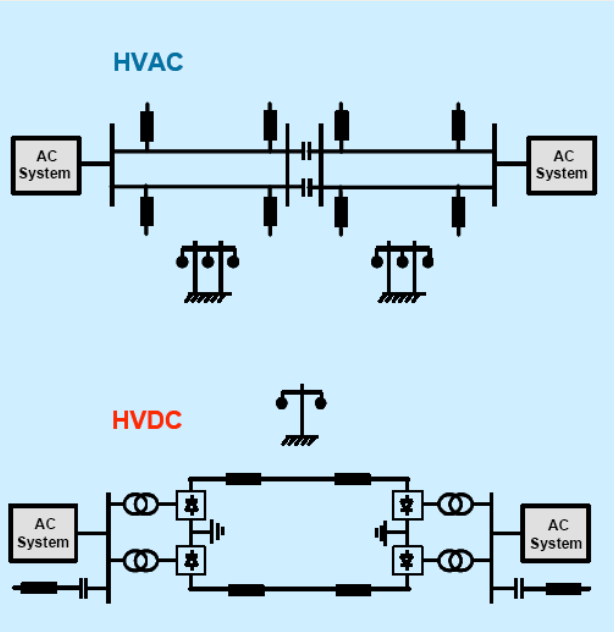


$I_d = (V_{d1} - V_{d2})/R$

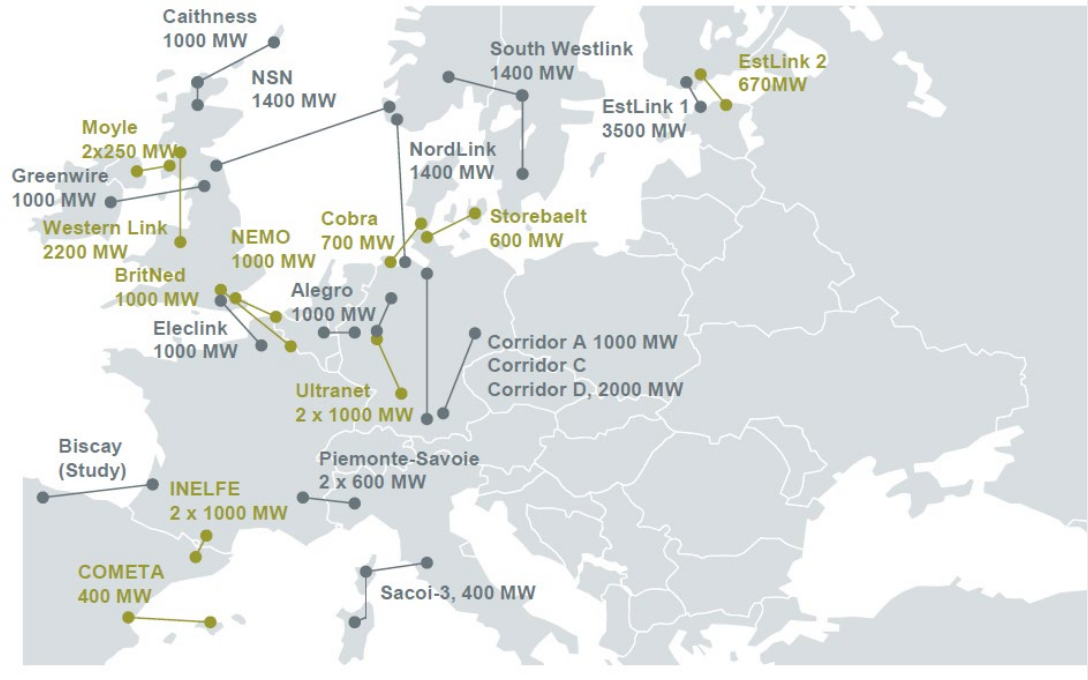
✓ And, therefore, the active power flow corresponds exactly to the Operator’s dispatch

HVDC Most Traditional applications

Long Distance OverheadTransmission



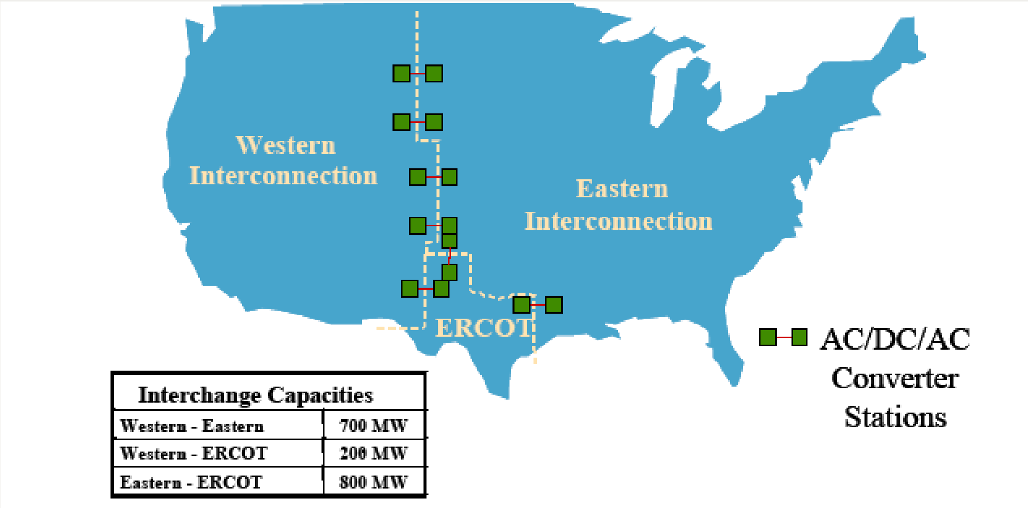
Interconnections with Submarine or Underground Transmission

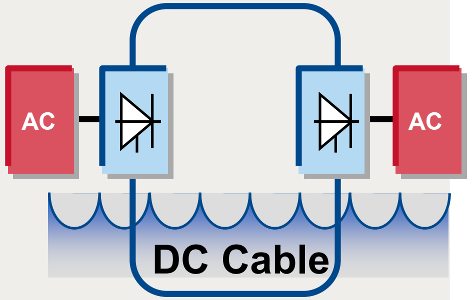


HVDC Most Traditional applications

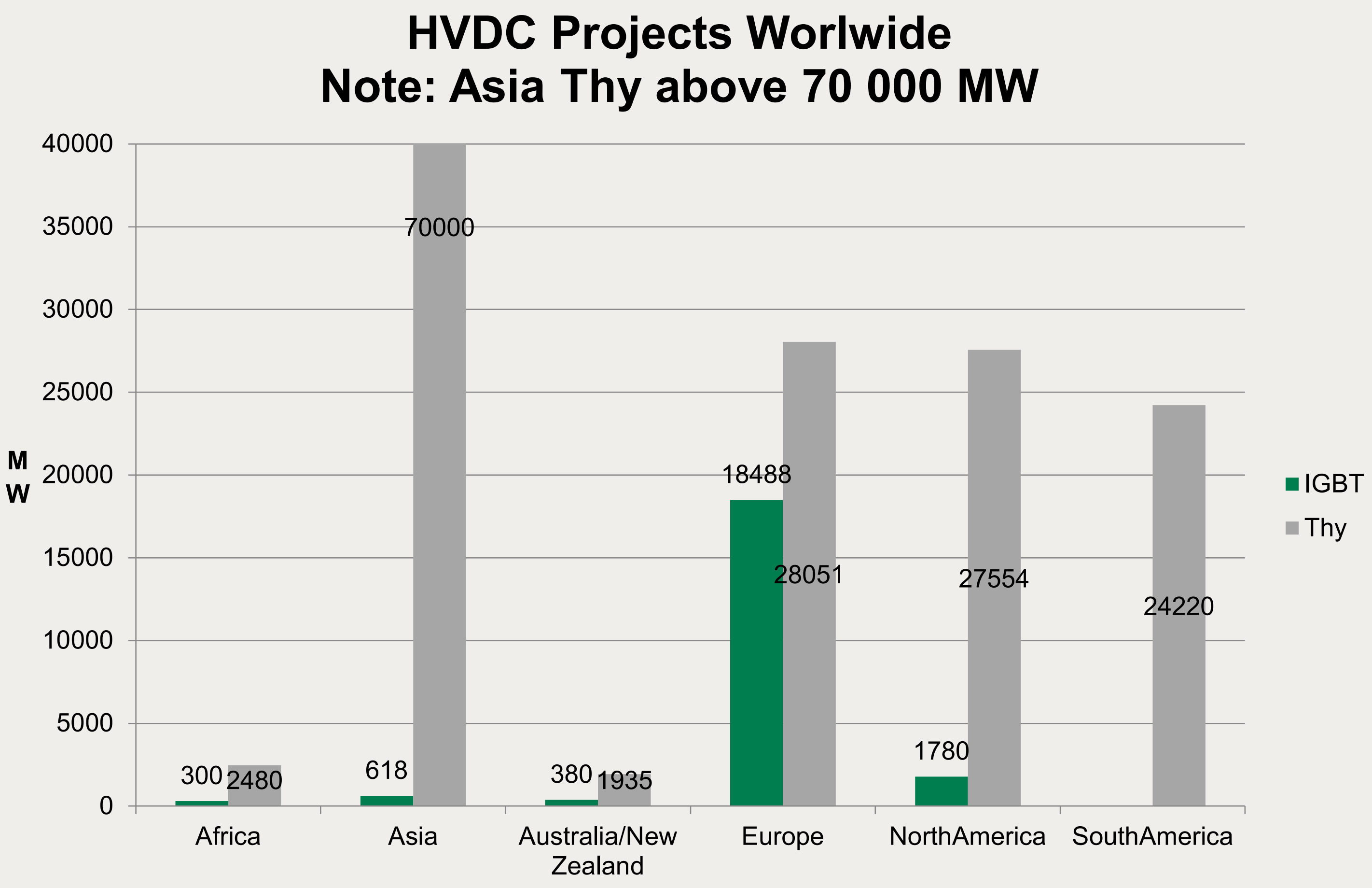
Back-to-Back from 50/60 Hz or Asynchronous Operations

Off- shore Wind Farms Integration





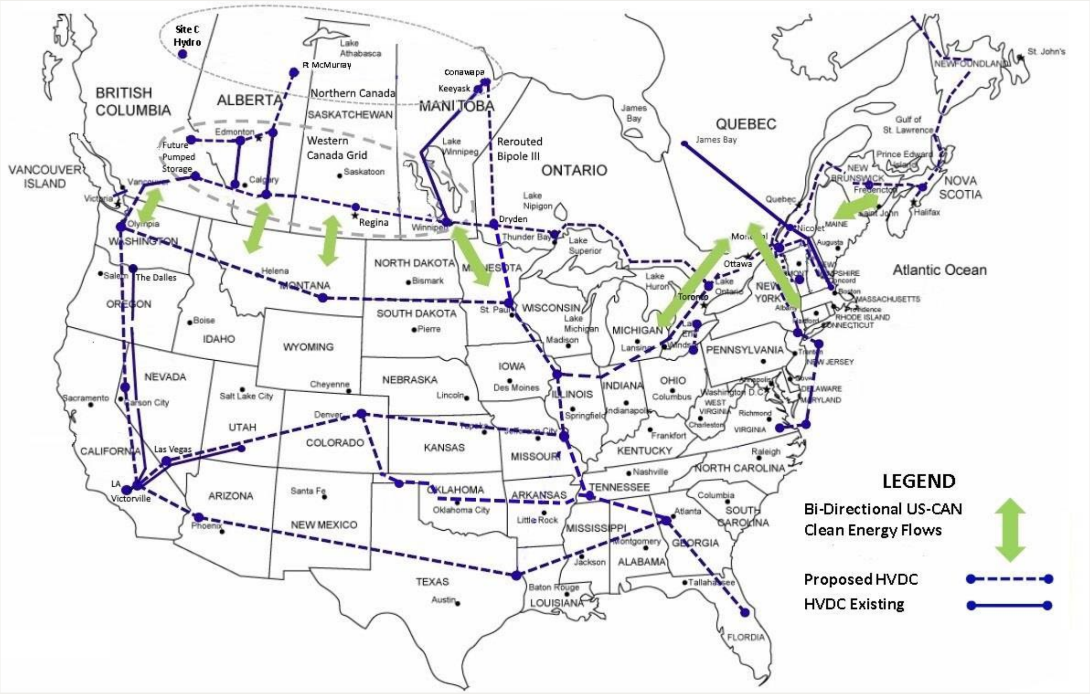
The HVDC Market (in 2018 close to 200 GW)



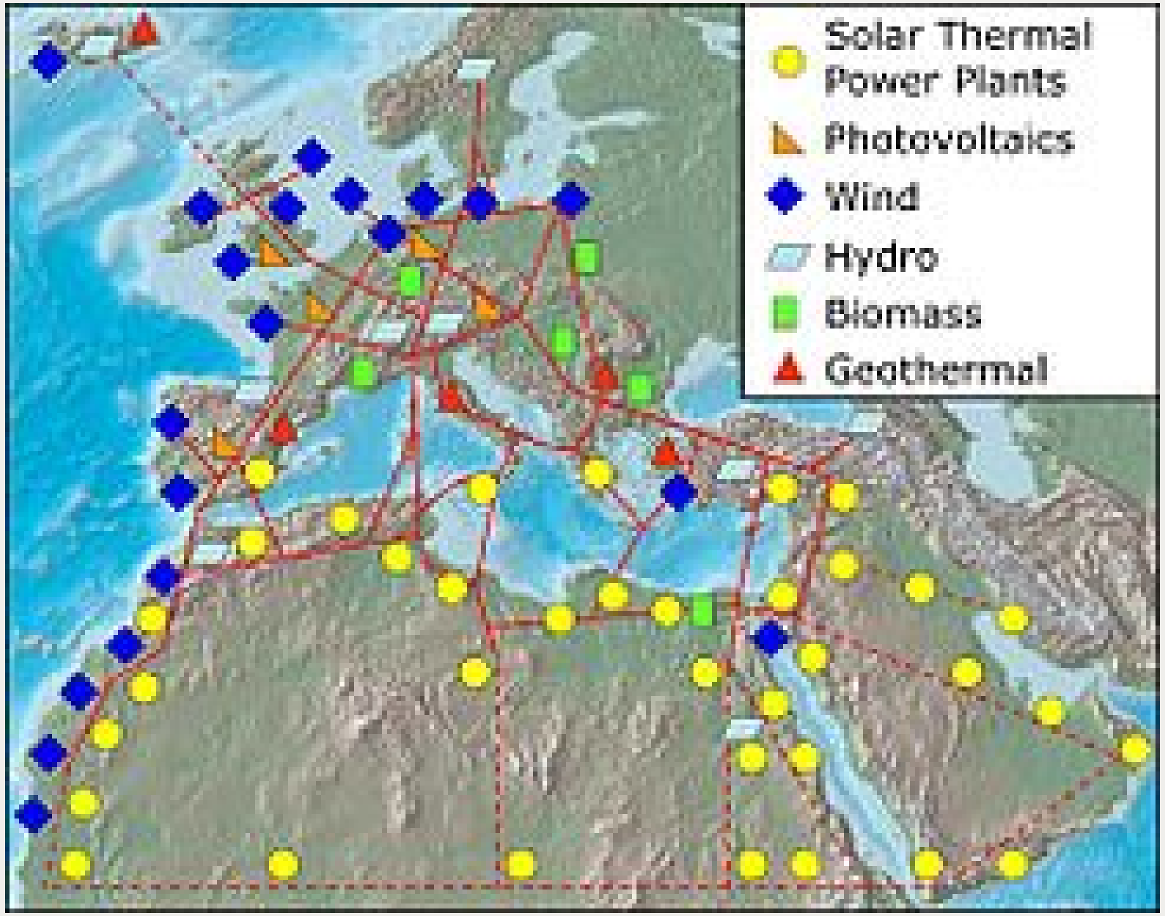
On new Market frontiers

The Asian Interconnection

The North American Overlay

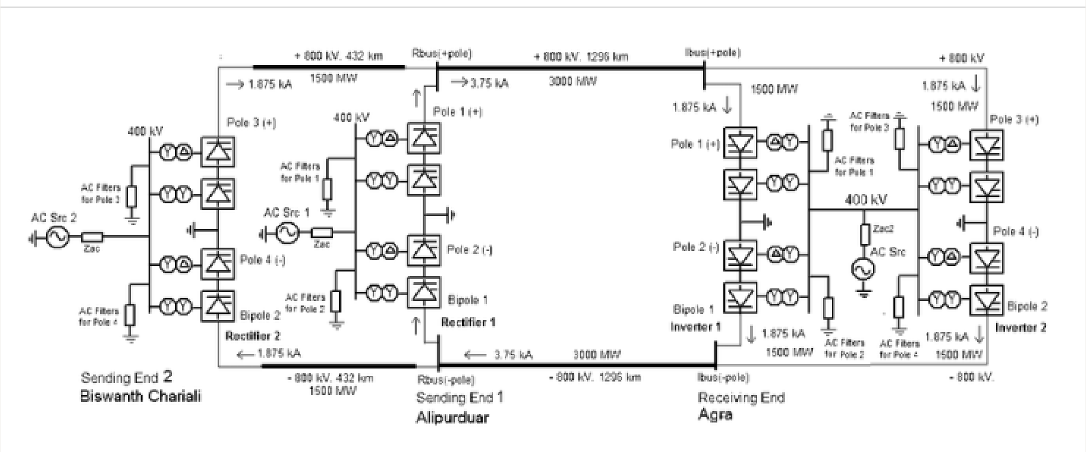


Or linking Africa to Europe

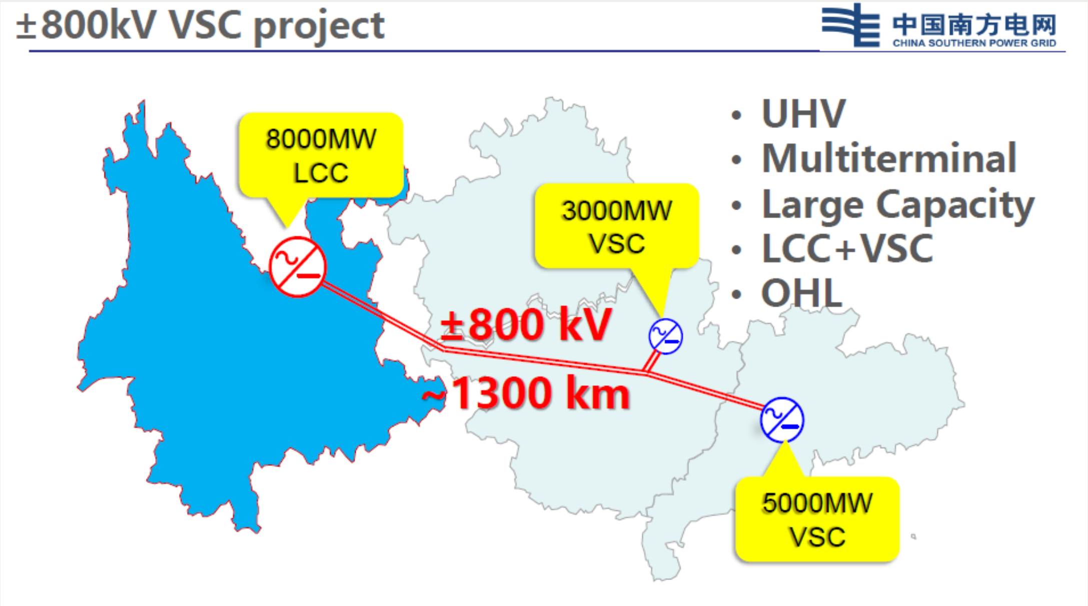


On HVDC Technological frontiers

The Conventional Multi-terminal (India – PGCIL)

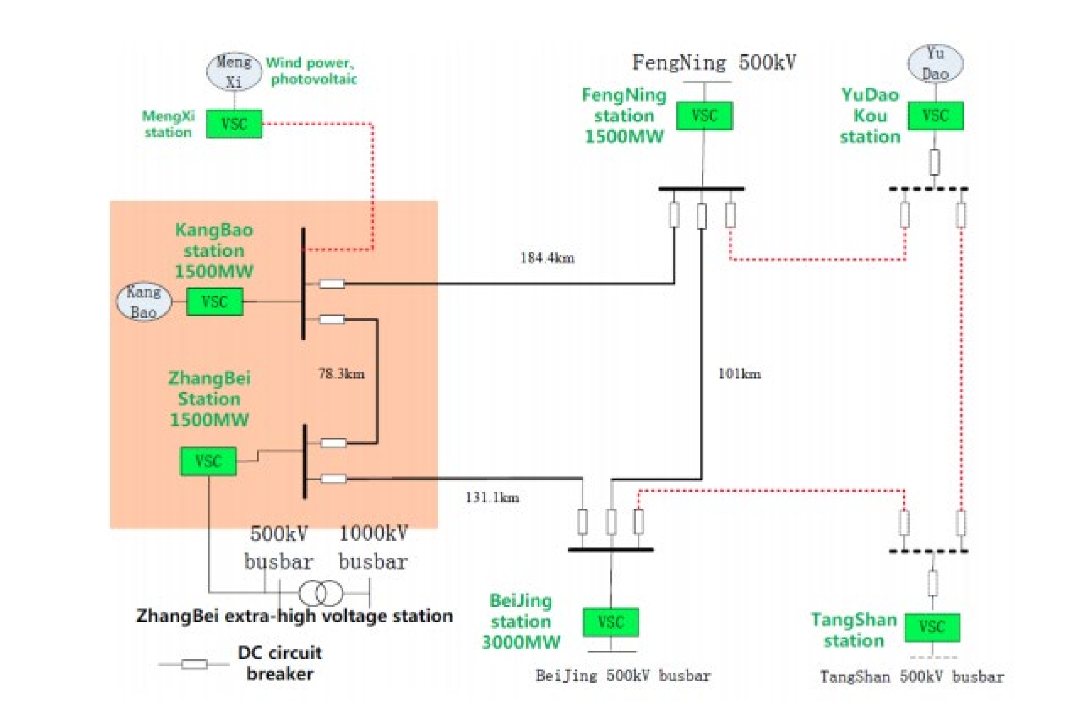


The New Multi-terminal China - CSG

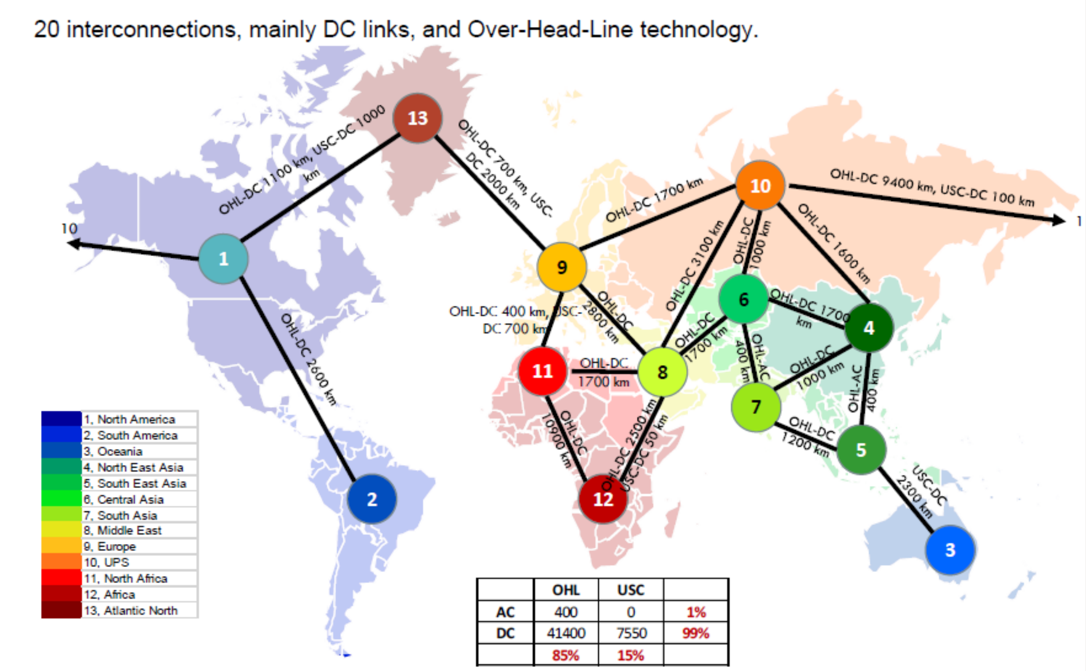


On future frontiers

HVDC Grids



Global Interconnections (CIGRE WG C1.35)



	OHL	USC	
AC	400	0	1%
DC	41400	7550	99%
	85%	15%	

T. Guangfu, "High Power Conversion Technology for High Voltage DC Transmission Application", in The Energy Conversion Congress and Exposition (ECCE), Milwaukee (United States of America), 2016.

TECHNOLOGY FOR GLOBAL GRID

TECHNOLOGY DEVELOPMENT IN UHV

The ±1100 kV, 12000 MW, 3300 km SGCC Project

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

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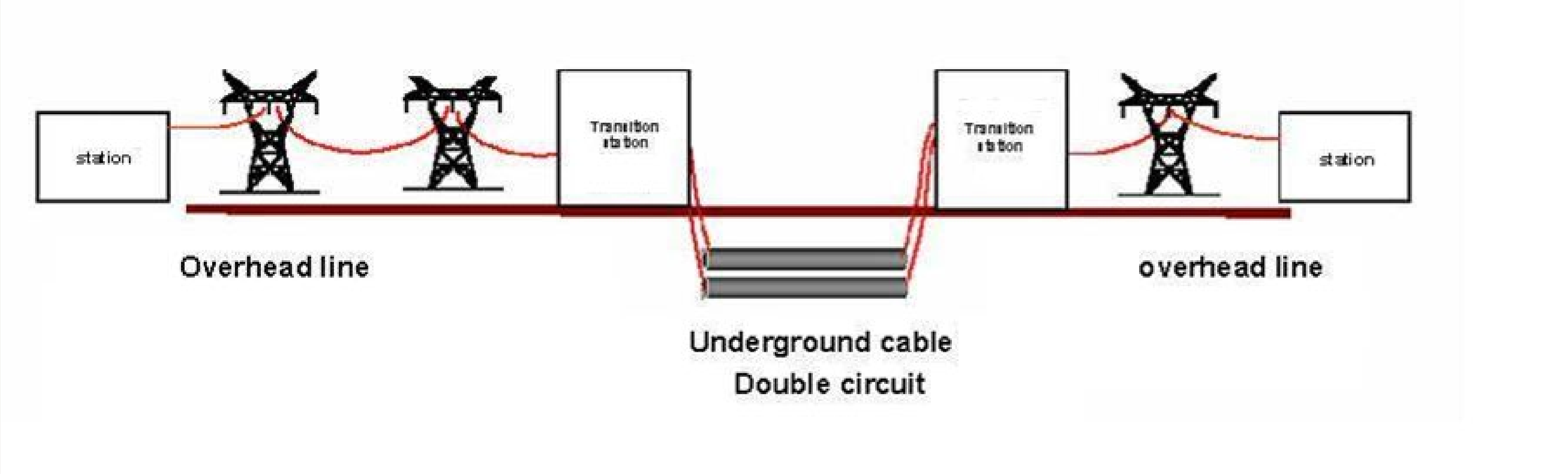
MOST LIKELY

Transnational Interconnections will be composed by OHL and UGC or SMC Cables configurations, mainly in most sensitive areas



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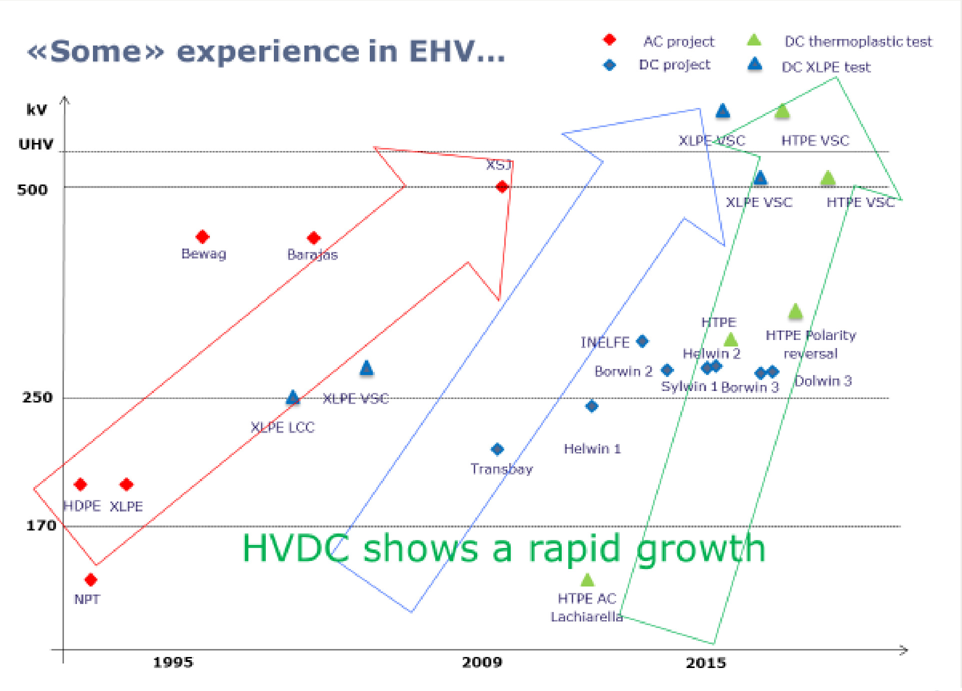
TECHNOLOGY ADVANCES IN CABLES (typical)

Year	Cable Voltage (kV)	Rated Power (MW)	Cable Length (km)
~2000	±150	300	100 - 250
~2010	±320	600	200 - 300
~2020	±600	3000	300 - 800
2030 (?)	±800 (?) ±1000 (?)	5000 (?) 7000(?)	



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HVDC TECHNOLOGIES KEY PARAMETERS COMPARISON

Technology	Line Commutated Converter (LCC)	Voltage Sourced Converters (VSC)
Semiconductor	Thyristor (Turn on only)	IGBT (Turn on/off)
Ratings	High DC Voltage and Power	Lower DC Voltage &Power
Power Control	Active Power	Active & Reactive Power
AC Filters	Required	Not Required (MMC)
Minimum SCR	>2	0
Black Start Capability	No	Yes
Overload	High inherent overload capabilities	Normally not unless specified
Footprint	Larger site (More space required for harmonic filters)	Compact, 50-60% of LCC
Configurations	Monopole, Bipole	Symmetric Monopole,, Bipole, Multi-terminal
Application	Point-to-Point, Back-to-Back Multi-terminal	Point-to-Point, Back-to-Back Multi-terminal, HVDC Grid
Dynamic Overload	Most used, such as 50% for 5 sec and 33% for 30 minutes	Power Ratings have to be increased

The Build-up of kV/MW through Multi-modular cells (MMC)

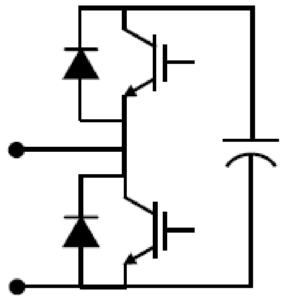


Figure 1 - Half bridge submodule

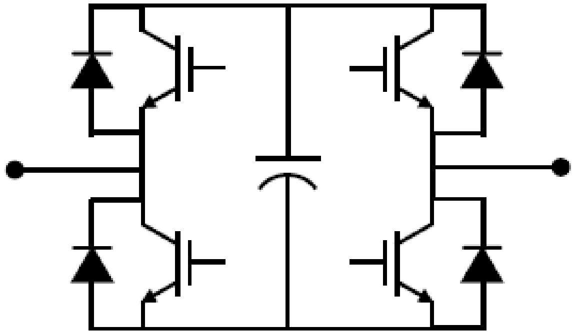
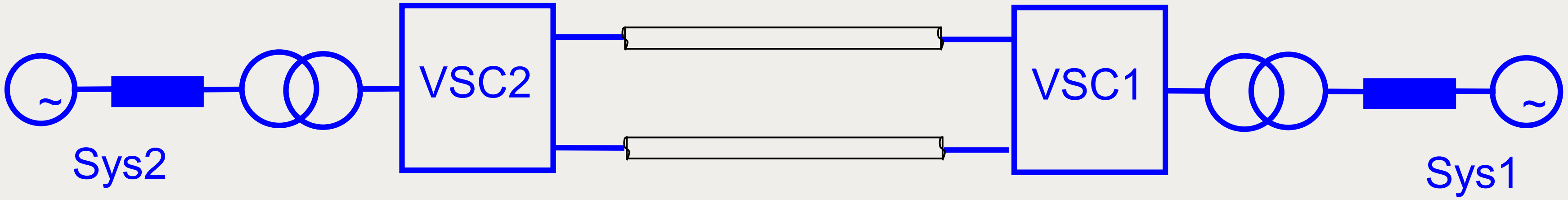


Figure 3 - Full bridge submodule

VSC Application

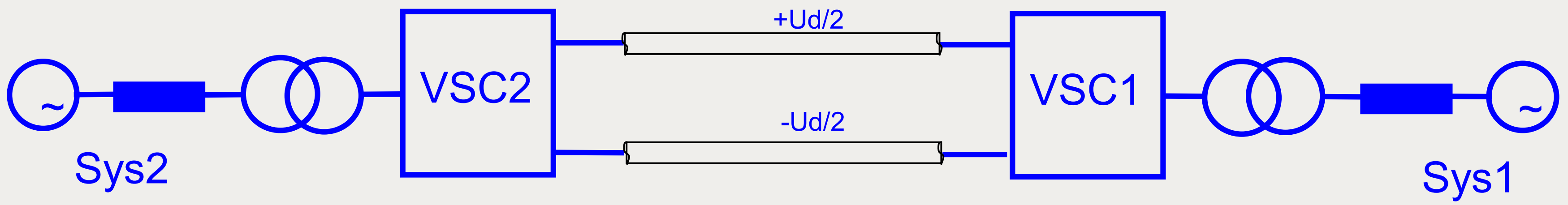
HVDC Transmission



- Similar to conventional HVDC, one station controls DC current and one station controls DC voltage
- Power reversal is through change of DC current direction, DC voltage polarity remains unchanged
- Reactive power is controlled independently at each terminal
- Can use XPLE cables (available up to 525kV)

VSC-HVDC Transmission

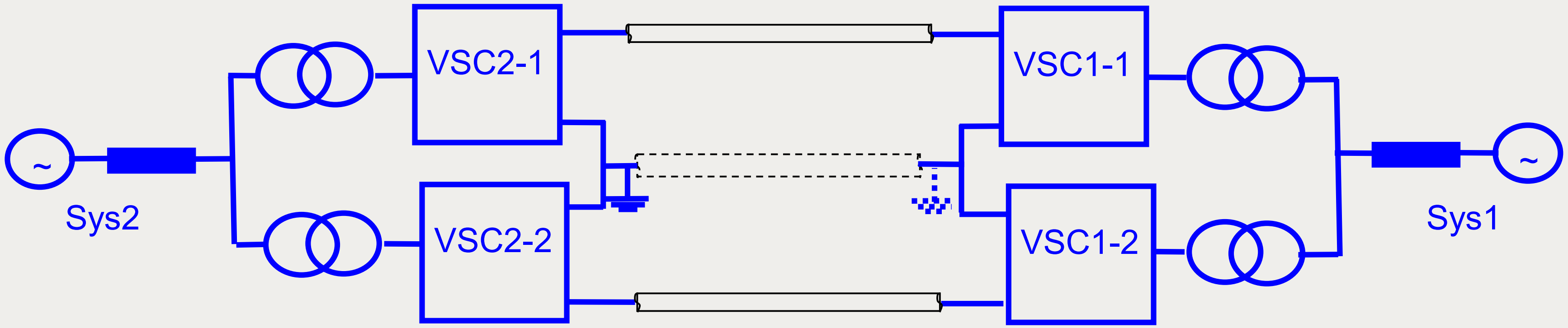
Symmetrical Monopole Configuration



- Regular AC transformer
- DC to ground fault does not cause high short circuit current, however requires a DC CB or AC CB action to eliminate current
- Uses two high voltage cables, each rated for Ud/2
- Can be realized with half bridge converters without extra equipment
- No power transfer capability with a monopole outage

VSC - HVDC Transmission

Bipolar Configuration



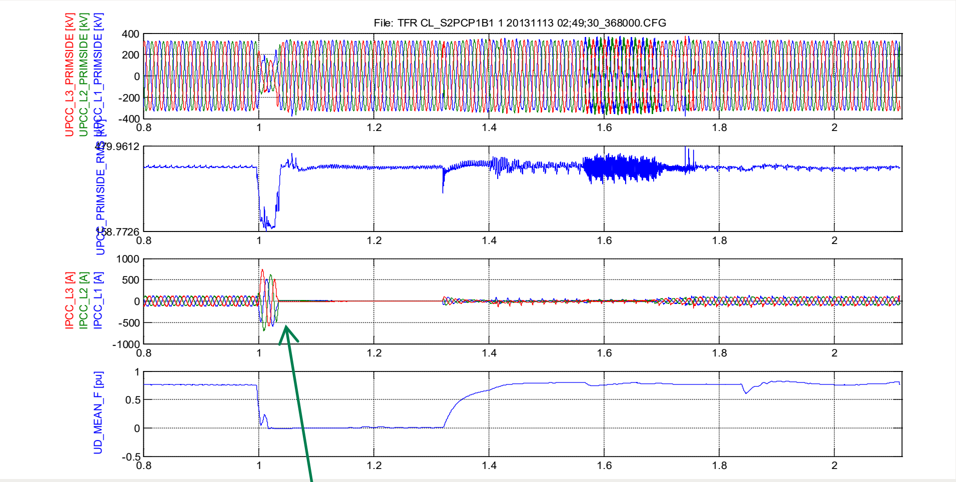
- Can have ground or metallic return
- Converter transformer (dc stress on secondary windings)
- DC to ground fault cause high short circuit current affecting AC systems (worse than LCC)
- Uses two high voltage conductors and possibly one low voltage conductor
- Can be realized with half bridge or full bridge converters, in case of HB requires extra equipment for DC and AC faults
- 50% (or more) power transfer capability with a monopole outage

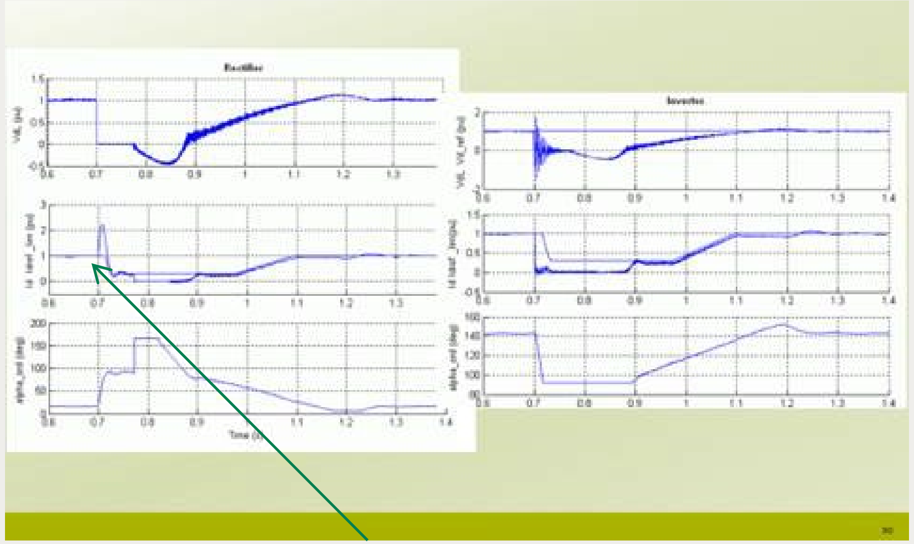
Fault Performance

Pole to ground fault in symmetrical monopole with HB (no DC CB)

- Will cause sudden discharge of cable
- Will cause overvoltage on the healthy conductor
- Will be detected and cause blocking of all sub-modules; a trip signal is issued at the same time
- After blocking the pole-pole DC is determined by diodes only (limited to peak phase-phase voltage)
- Normally cleared by opening AC breakers at both ends, can restart after discharging the cable

LCC and VSC Responses to a DC Line fault



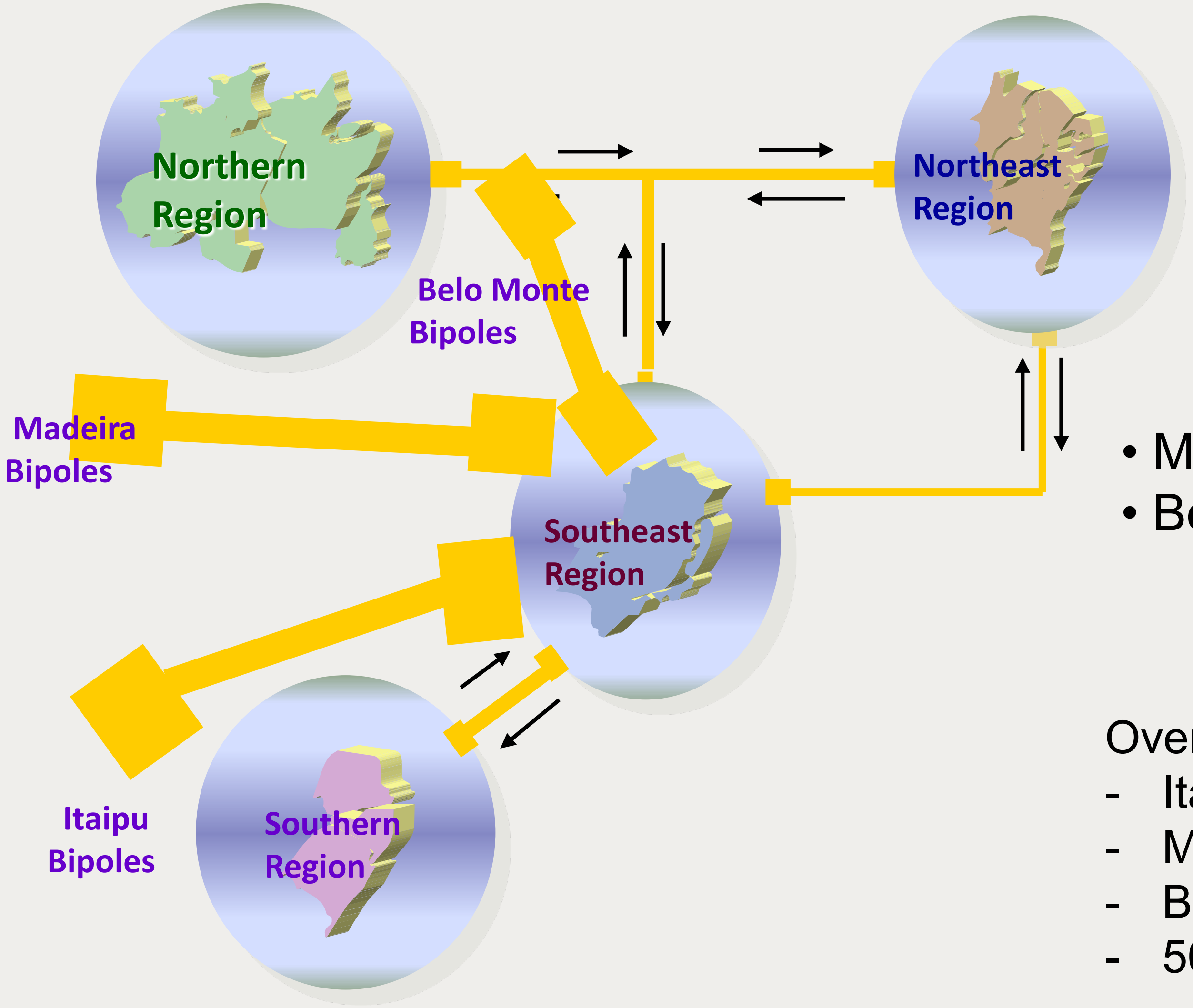


Fault current cleared by AC breaker (3 cycles); full recovery time, from 700 to 1500 ms; with DC breakers or full bridge, time will be less

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

The Brazilian Transmission Grid
New Paradigms

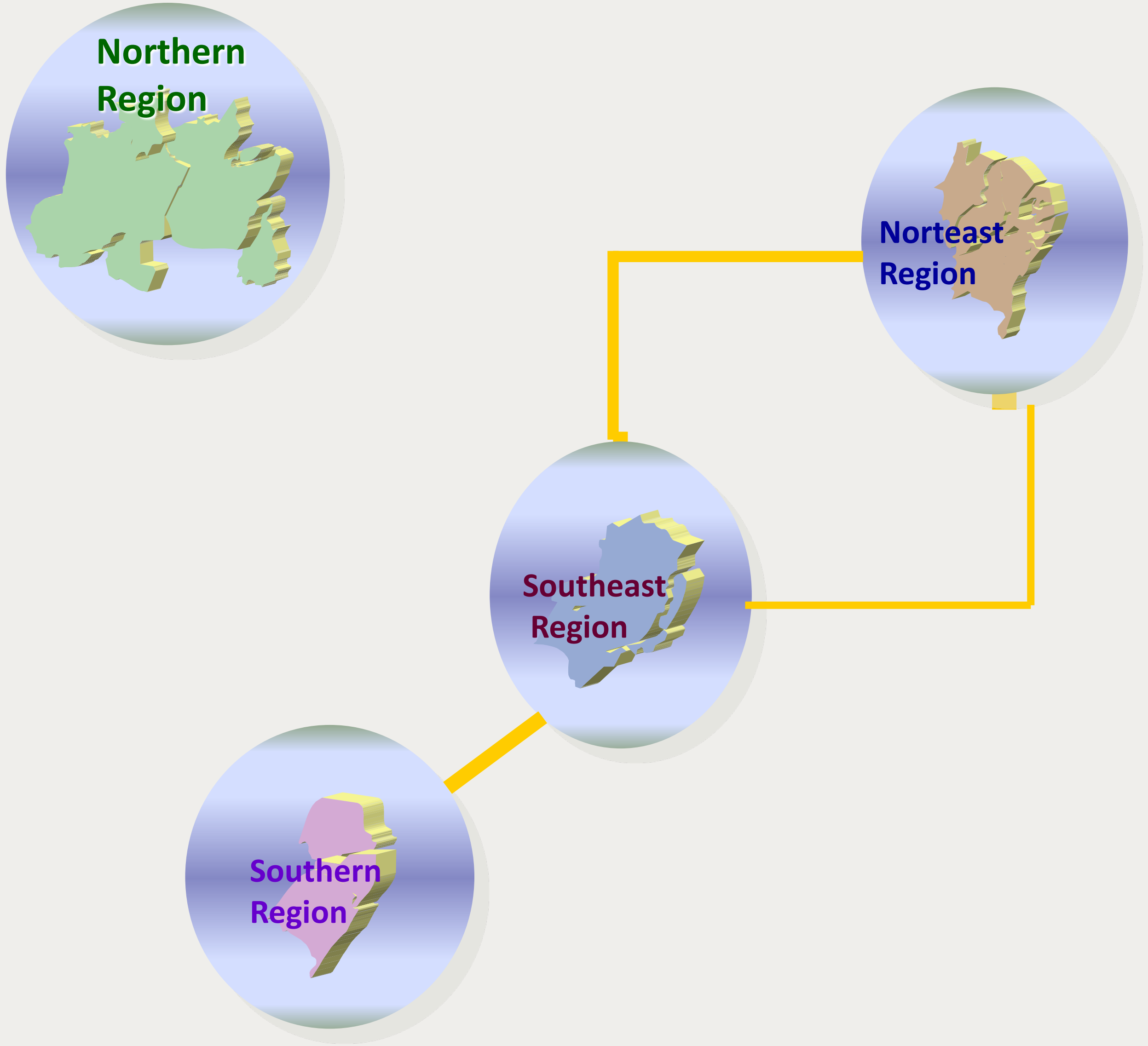


- Madeira and Itaipu: assinchronous
- Belo Monte: system embedded and bi-directional

Overload capability (30 min) specified:

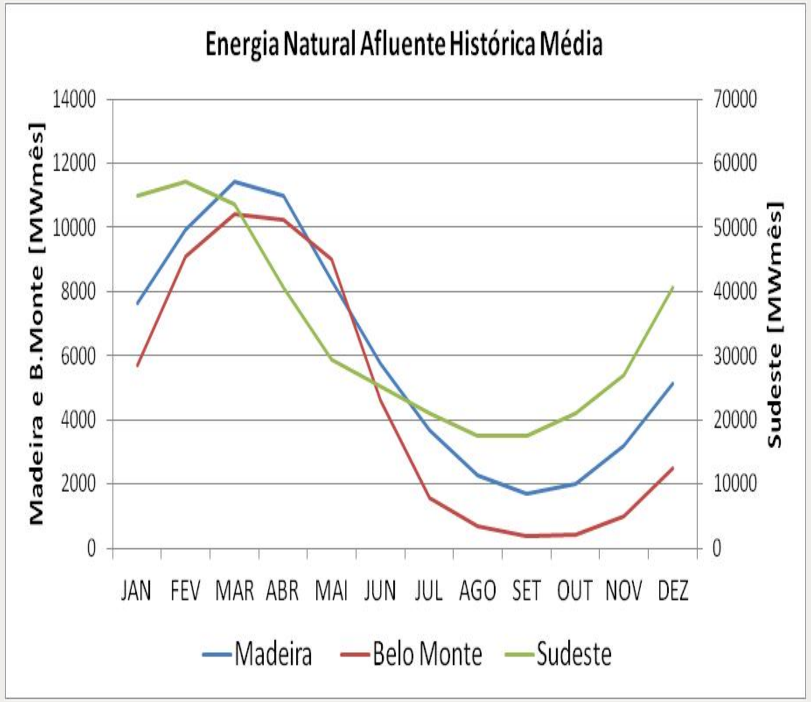
- Itaipu: 10% for a Pole Contingency
- Madeira: 33% for any DC Contingency
- Belo Monte: 33% for any AC or DC event
- 50% for the first 5 seconds

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**

CONCLUSIONS

- No return trends:
  - The more active role of the Distribution Systems
  - The massive interchange of information and cyber security aspects
  - Increase use of Renewable Energy Resources
  - Hydropower potential use to firm up other renewable (intermittent)
  - To envisage a future life we need to reduce fossil fuel resources
  - Large transmission Interconnections are unavoidable to make feasible the predominant use of RES

- Are the OHL/UGC/SMC cables Technologies new developments in line with those trends?

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THANK YOU FOR YOUR ATTENTION

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